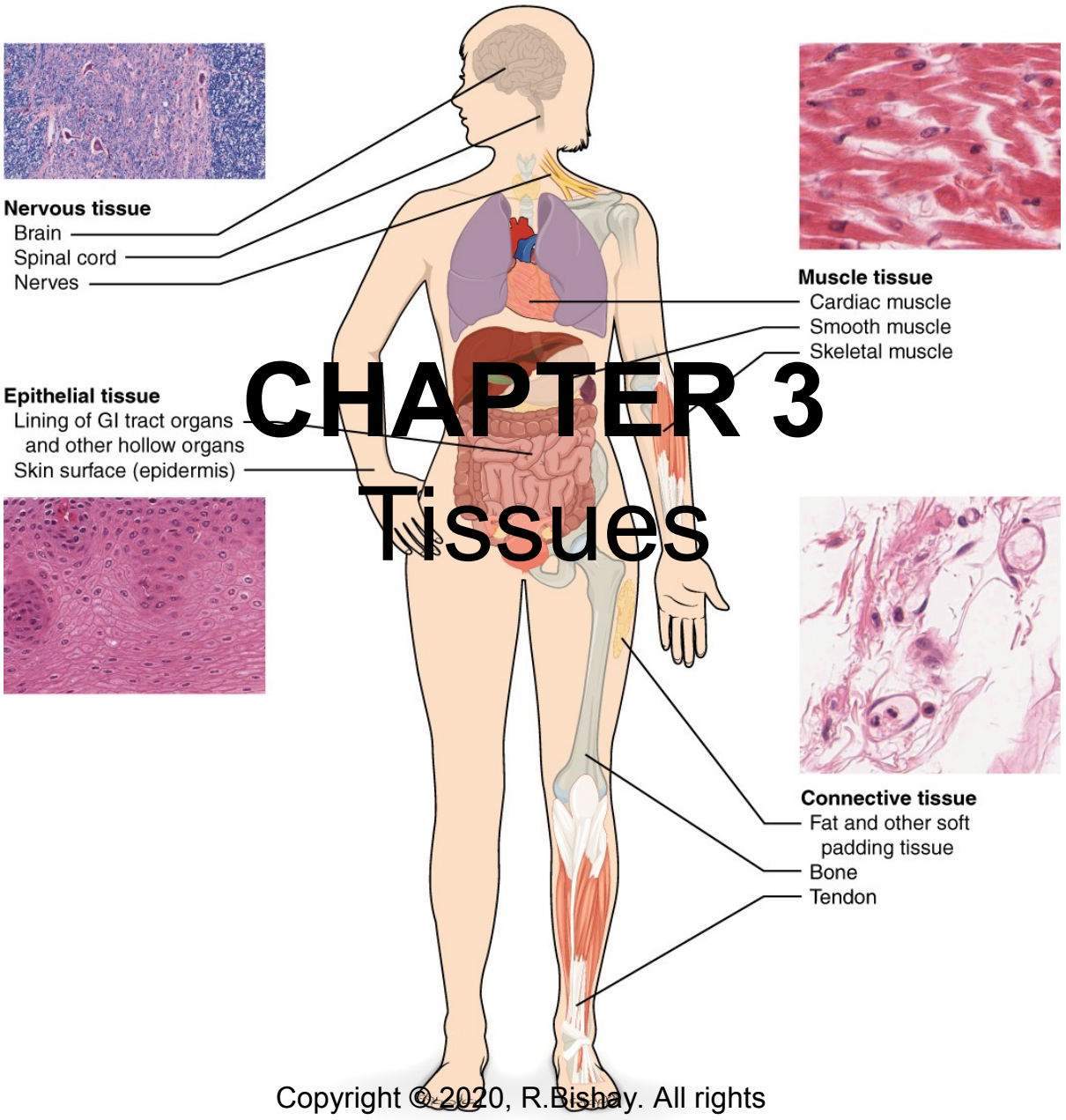

CHAPTER 3
Tissues

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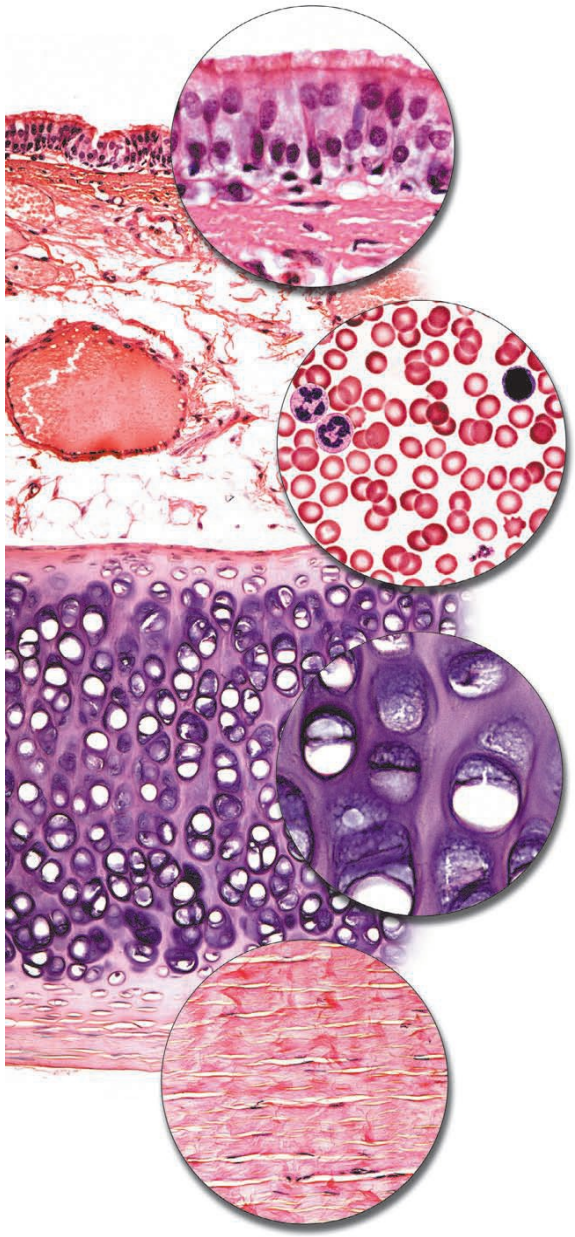

Tissues

A tissue is a group of similar cells that usually have
•a common embryological origin AND
function together to carry out specialized activities.

Tissues vary tremendously
•the kinds of cells present,
•how the cells are arranged, and
•the types of fibers present, if any.

The structure and properties of a specific tissue are influenced by:
•the nature of the extracellular material that surrounds the tissue cells
•the connections between the cells that compose the tissue.

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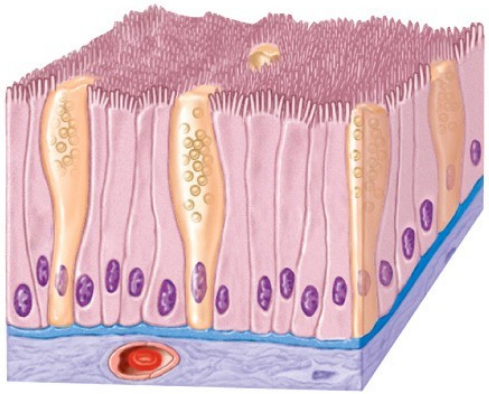
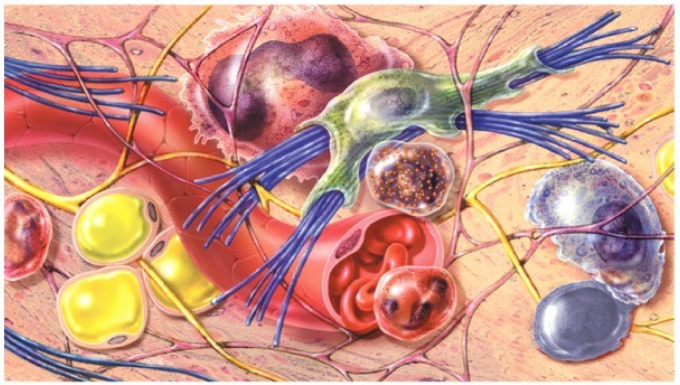
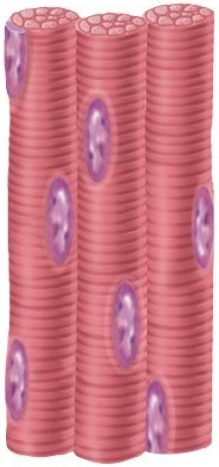
4 Major Types of Tissues



(a) Epithelial tissue



(b) Connective tissue



(c) Muscular tissue

(d) Nervous tissue

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Four major families of tissues

- **Epithelial tissue**
  - covers body surfaces
  - lines hollow organs, body cavities, and ducts
  - forms glands
- **Connective tissue**
  - protects and supports the body and its organs
  - binds organs together
  - stores energy reserves as fat
  - provides immunity
- **Muscular tissue**
  - generates physical force for movement and thereby generates body heat
- **Nervous tissue**
  - detects changes in a variety of conditions IN and OUT side of the body
  - responds by initiating and transmitting nerve impulses (signals) that help control and coordinate body activities

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Four major families of tissues

Epithelial tissue and most types of connective tissue, except cartilage, bone, and blood, are more general in nature and have a wide distribution in the body.
These tissues **are components of most body organs** and have a wide range of structure and function.

Epithelial tissue: allows the body to interact with both its internal and external environments.

Muscular tissue contraction

Nervous tissue detects changes in a variety of conditions inside and outside the body and responds by generating electrical signals called nerve action potentials (nerve impulses) that activate muscular contractions and glandular secretions.

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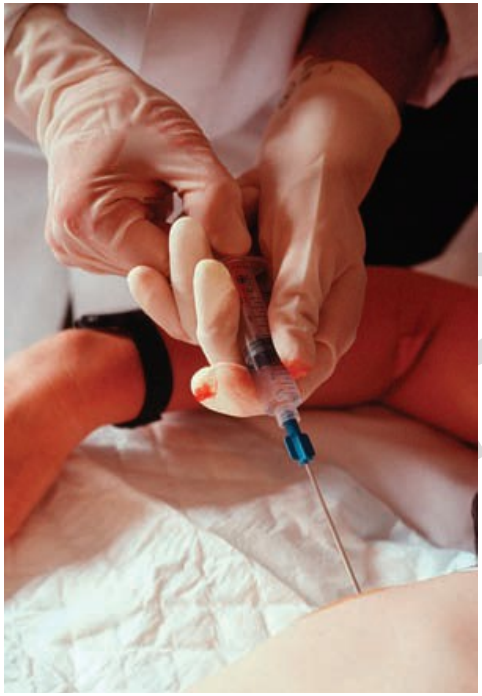
Histology: the science that deals with the study of tissues.

Pathologist: A physician who specializes in laboratory studies of cells and tissues to help other physicians make accurate diagnoses. One of the principal functions of a pathologist is to examine tissues for any changes that might indicate disease.



Biopsy

- the removal of a sample of living tissue for microscopic examination.
- used to help diagnose many disorders, especially cancer, and to discover the cause of unexplained infections and inflammations. Both normal and potentially diseased tissues are removed for purposes of comparison.

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HOW ARE CELLS HELD TOGETHER?

Most epithelial cells and some muscle and nerve cells are tightly joined into functional units.

Cell Junctions are points of contact between neighboring plasma membranes.

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Cell Junctions

There are five major types of cell junctions

- Tight junctions
- Adherens junctions
- Desmosomes
- Hemidesmosomes
- Gap junctions

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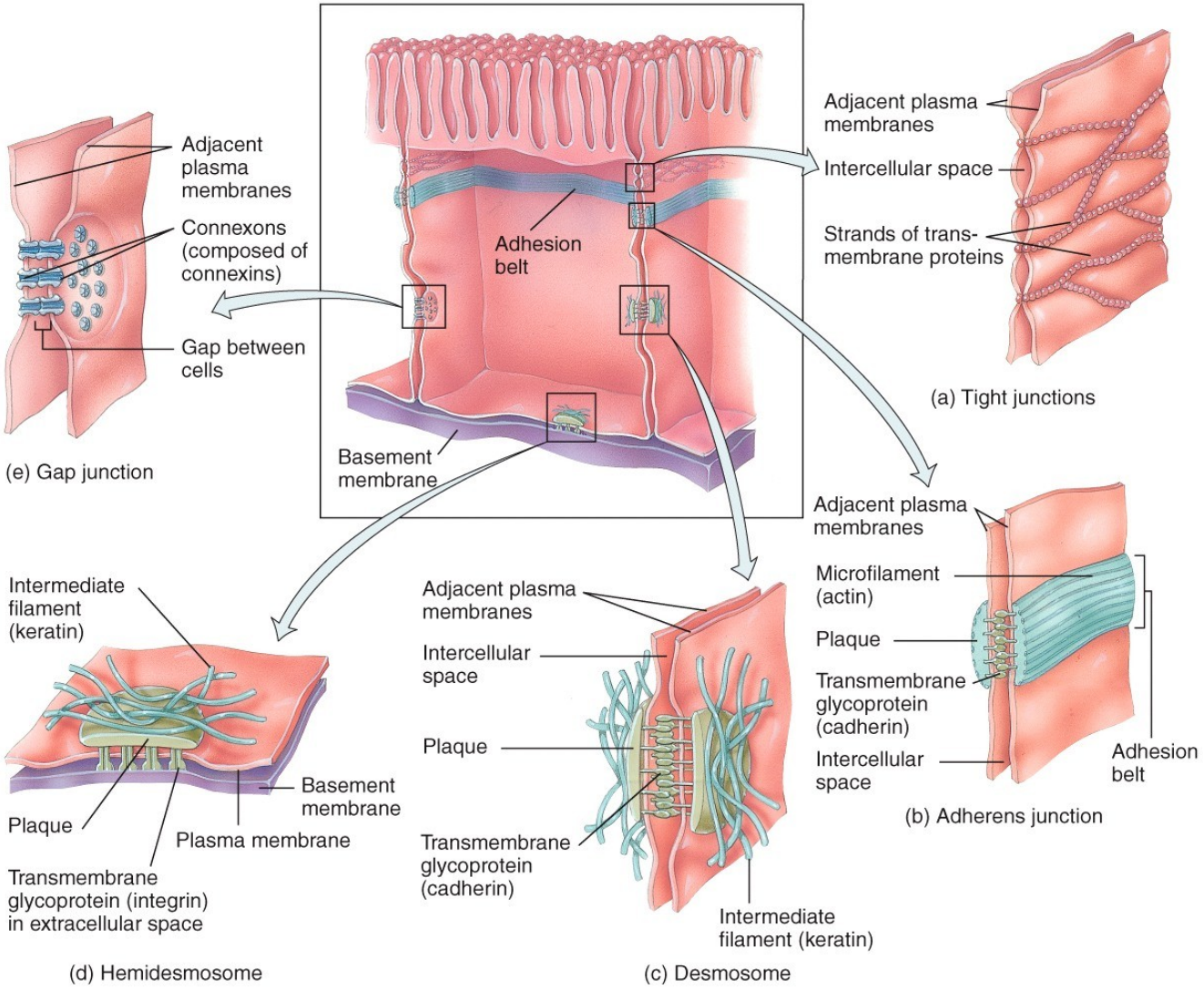
Cell Junctions



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Animation:

- Intercellular Junctions

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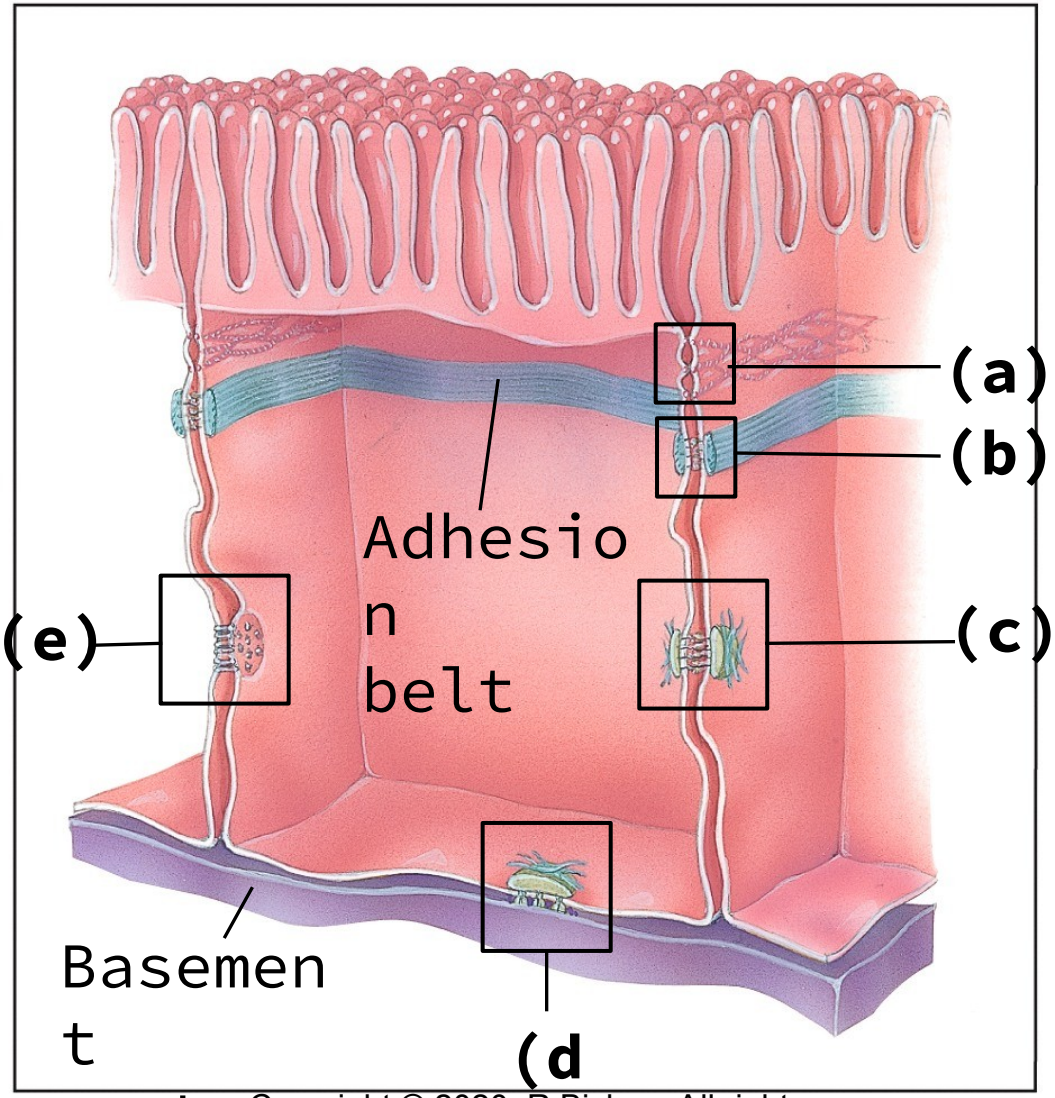
Cell Junctions



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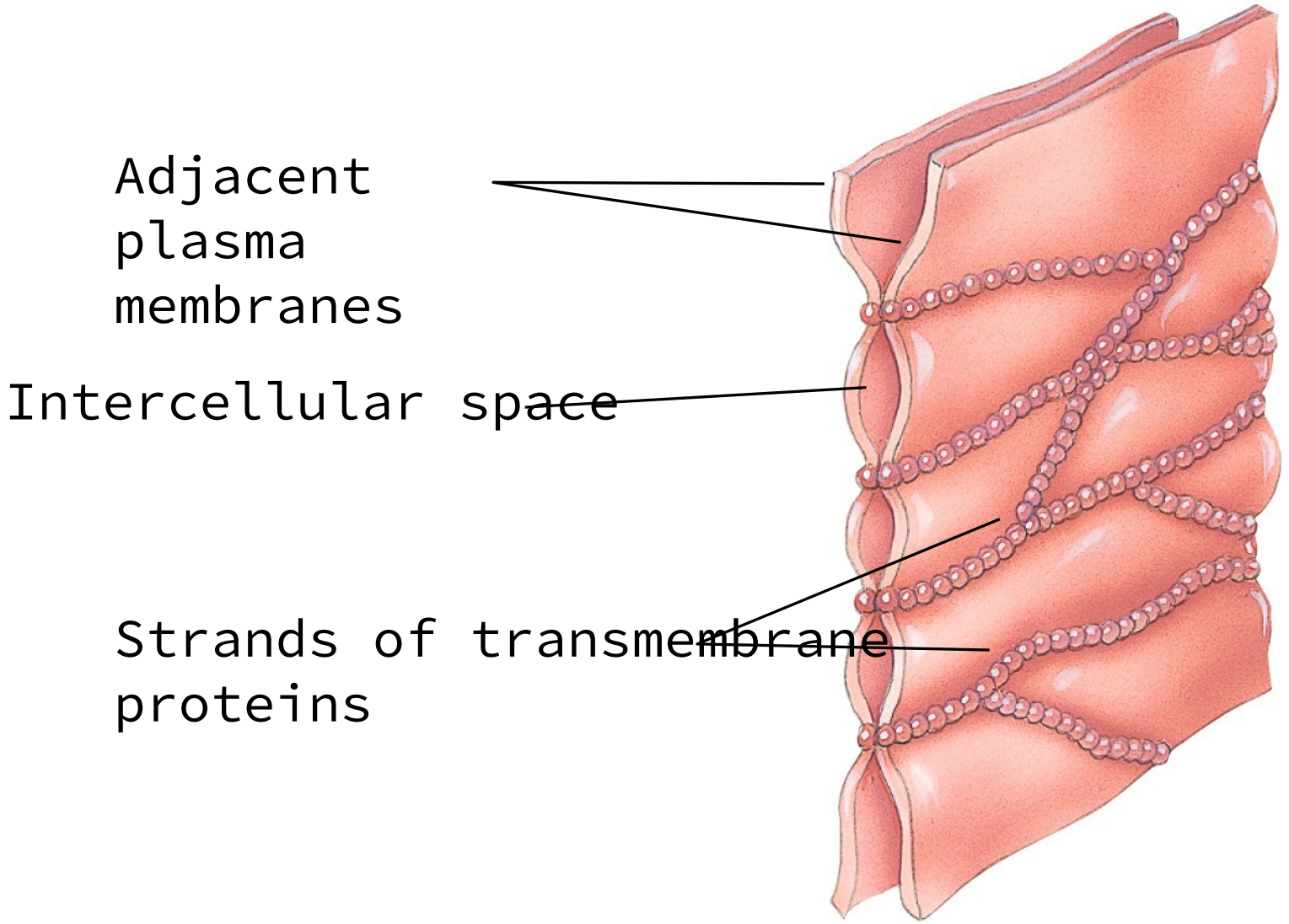

(a) Tight junctions

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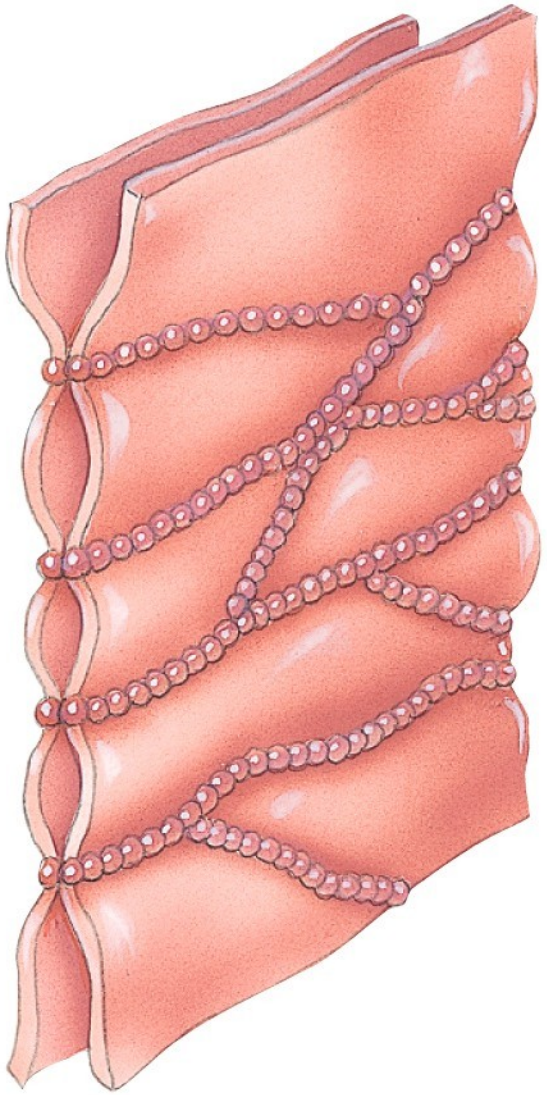
TIGHT JUNCTIONS

•consist of weblike strands of transmembrane
proteins that fuse together the outer surfaces of adjacent plasma membranes to seal off passageways between adjacent cells

•form tight seals between cells such as the epithelial cells that comprise the inner lining of the **stomach, intestines, and urinary bladder**

•prevent the passage of substances between cells

•prevent the contents of these organs from leaking into the blood or surrounding tissues.



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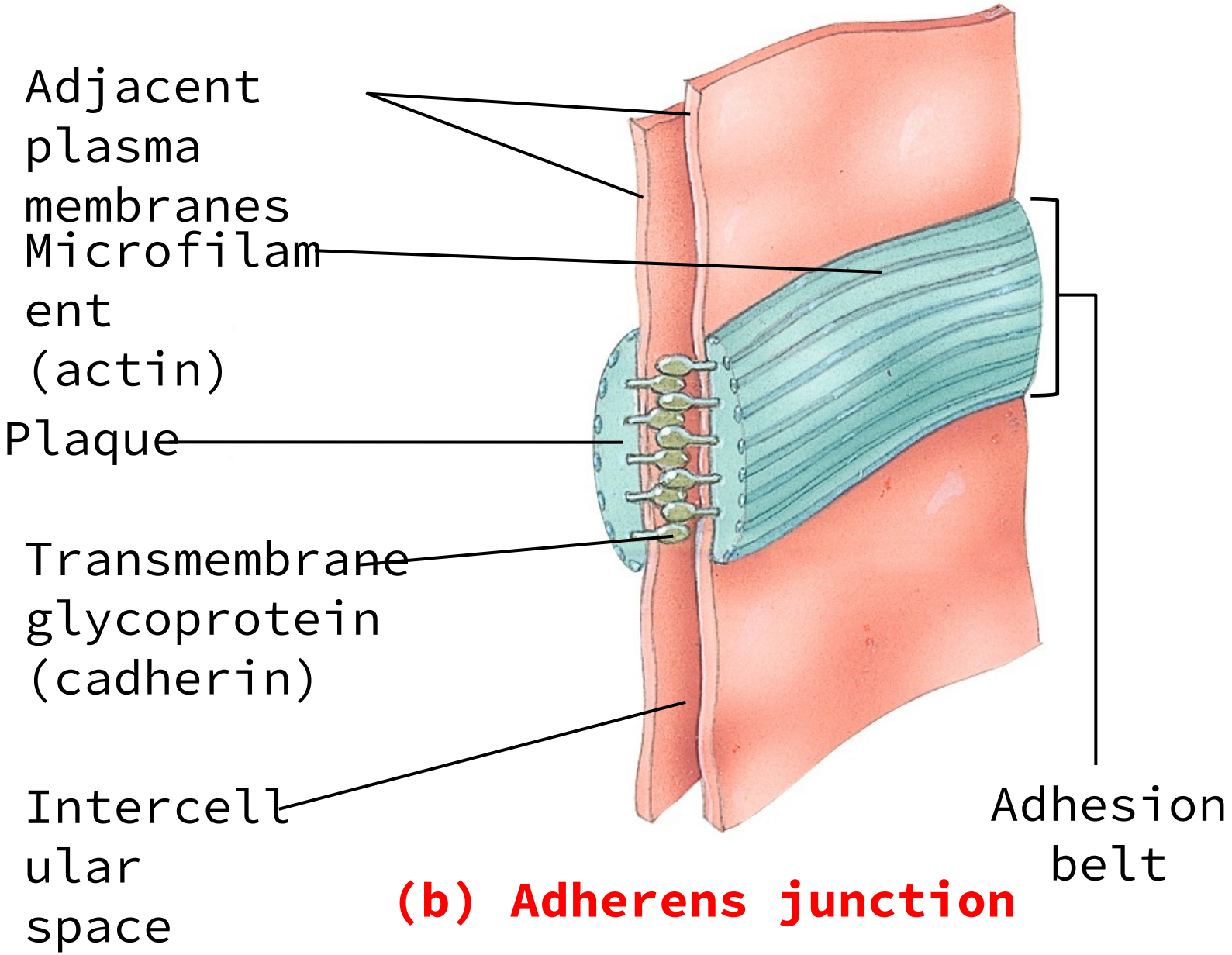

(b) Adherens junction

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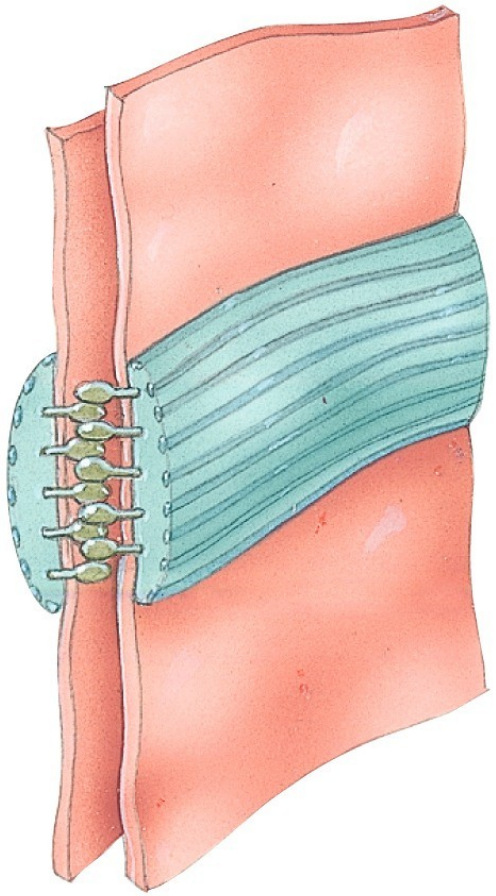
ADHERENS JUNCTIONS

Contain **plaque:** a dense layer of proteins on the inside of the plasma membrane that attaches both to membrane proteins and to microfilaments of the cytoskeleton.



Cadherins: Transmembrane glycoproteins that join cells. Each cadherin

- **inserts into the plaque** from the opposite side of the plasma membrane
- **partially crosses** the intercellular space
- **connects to a cadherin** of an adjacent cell

In *epithelial* cells, adherens junctions often form extensive zones called ***adhesion belts*** because they encircle the cell similar to the way a belt encircles your waist.

FUNCTIONS:
Adherens junctions help **epithelial surfaces** resist separation during various contractile activities, as when food moves through the intestines.

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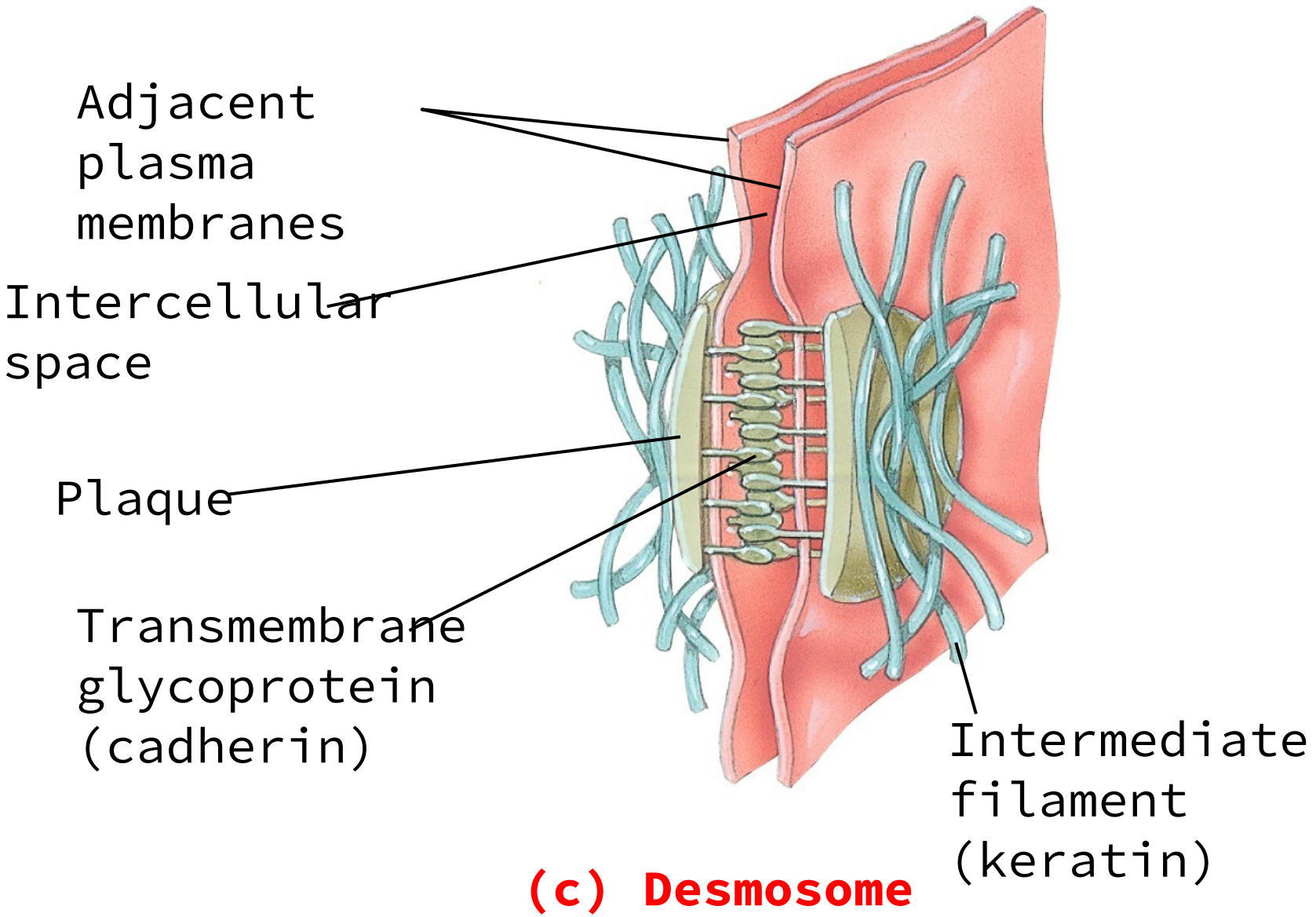

(c) Desmosome

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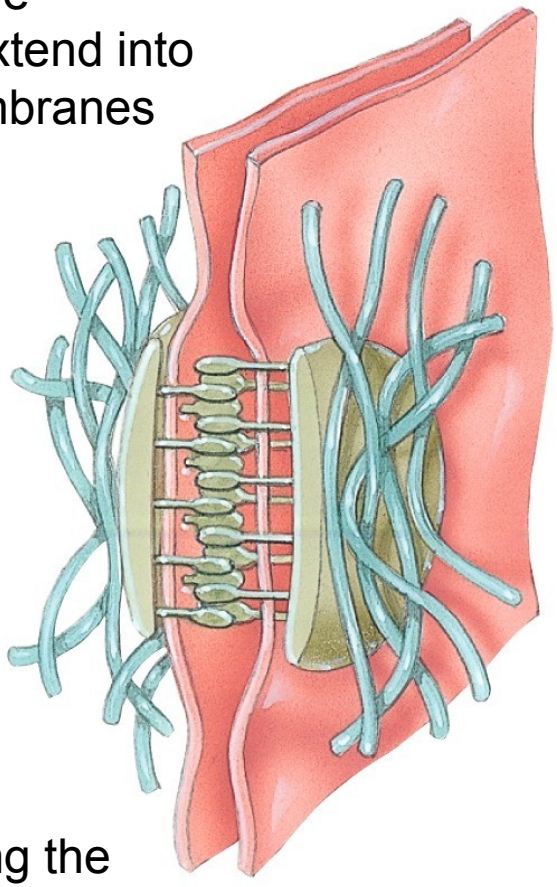
DESMOSOMES

Like adherens junctions: ***contain plaque*** and have transmembrane glycoproteins **(*cadherins*)** that extend into the intercellular space between adjacent cell membranes and attach cells to one another



Unlike adherens junctions, the plaque of desmosomes attaches to elements of the cytoskeleton known as **intermediate filaments**, which consist of the protein ***keratin*.**
The intermediate filaments extend from desmosomes on one side of the cell across the cytosol to desmosomes on the opposite side of the cell. This structural arrangement Contributes to the stability of the cells and tissue.

These spot-weld-like junctions are common among the cells that make up the **epidermis (the outermost layer of the skin)** and among **cardiac muscle cells** in the heart.

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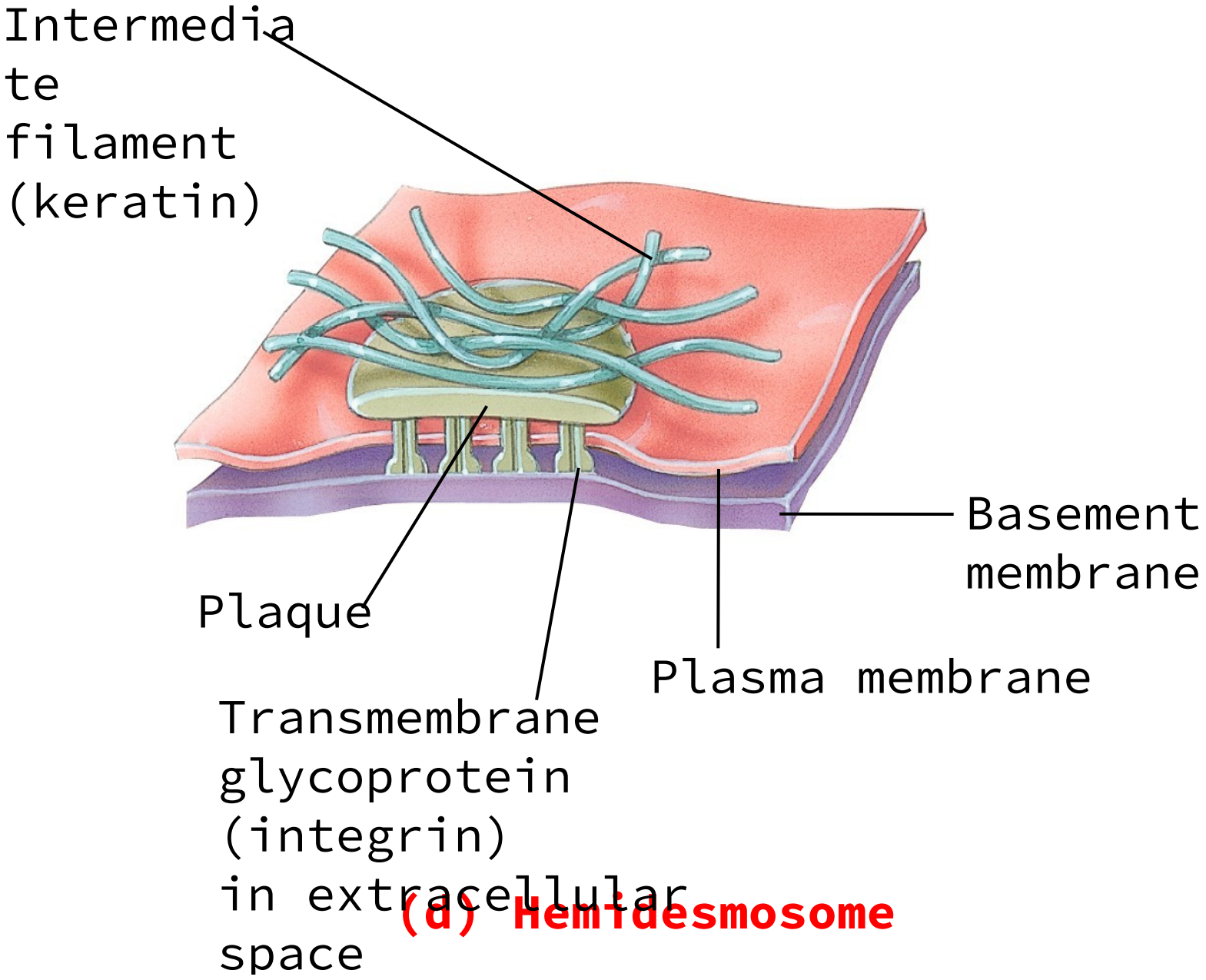

(d) Hemidesmosome

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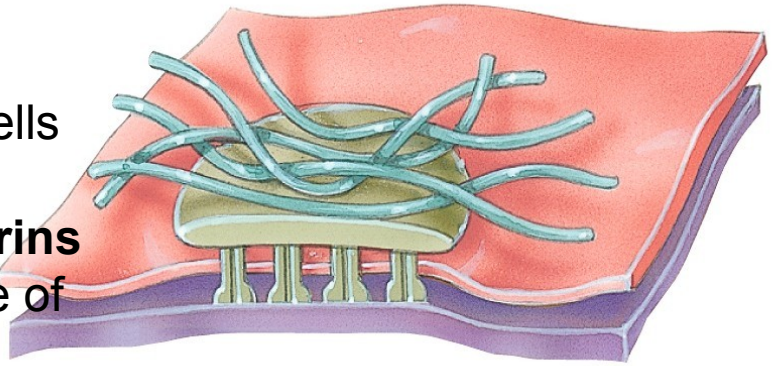
HEMIDESMOSOMES resemble desmosomes

•strongly anchor cells to an underlying basement membrane not to adjacent cells

•ON THE INSIDE OF THE CELL **integrins** attach to ***intermediate filaments*** made of the protein ***keratin***

•ON THE OUTSIDE OF THE CELL, **integrins** attach to the protein ***laminin,*** which is present in the basement membrane



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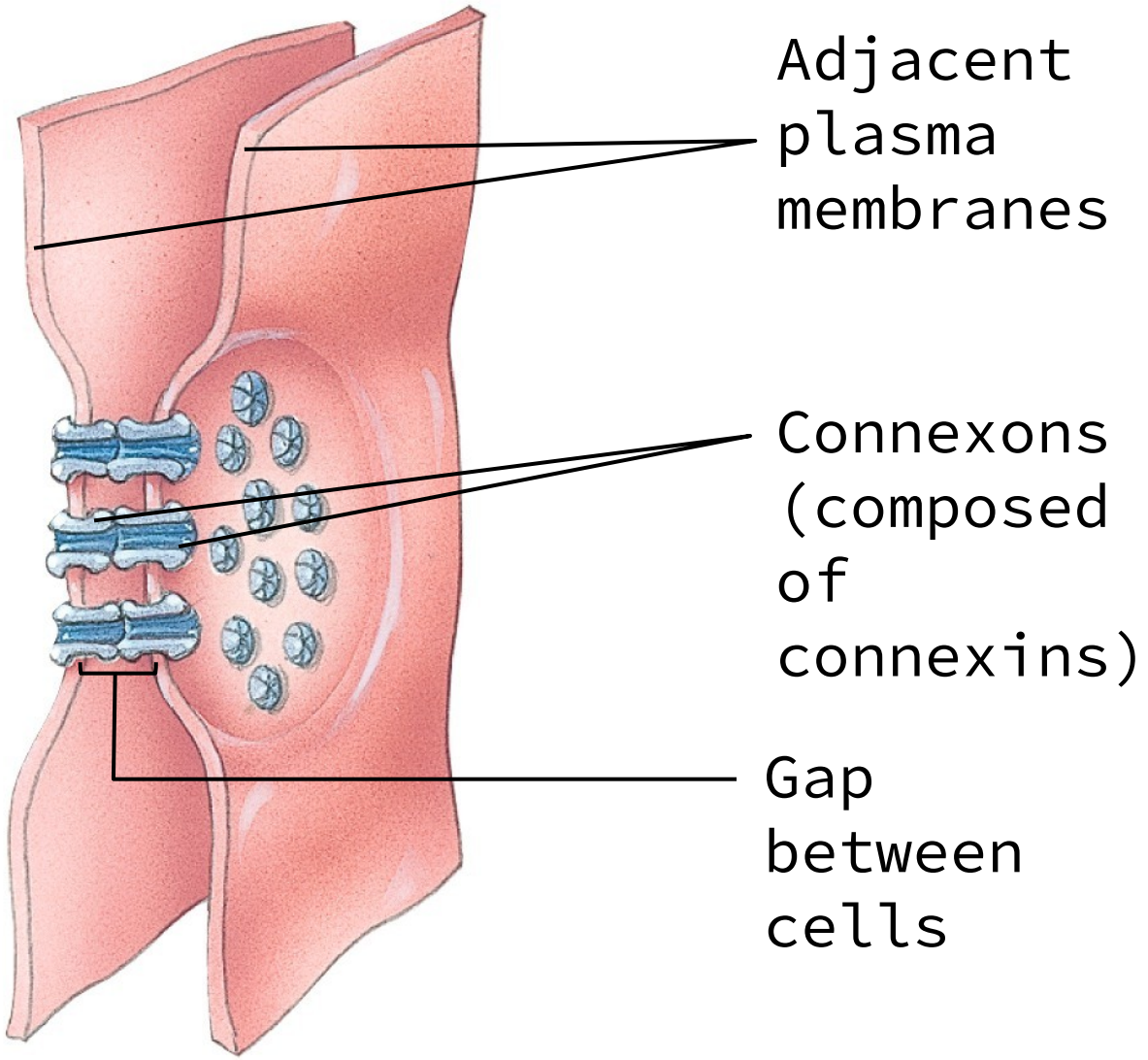

(e) Gap junction

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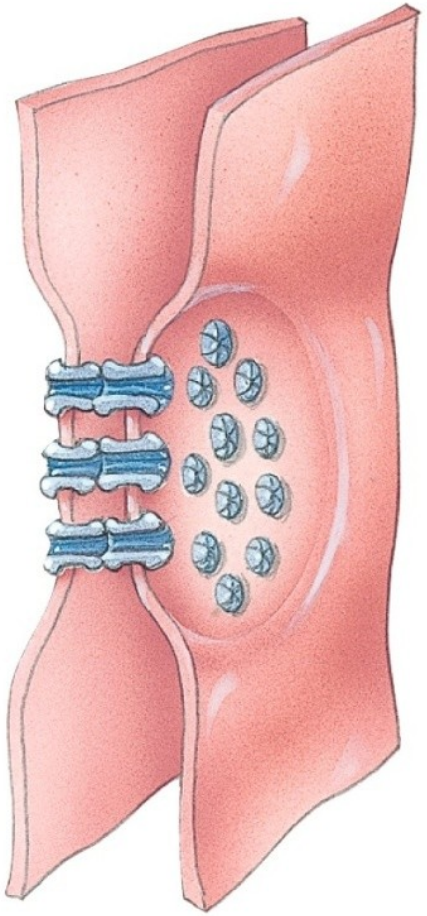
GAP JUNCTIONS

Unlike the fused plasma membranes of tight
junctions, the plasma membranes of gap junctions are separated by a very narrow intercellular gap (space). Membrane proteins called **connexins** form tiny fluid-filled tunnels called *connexons* that connect neighboring cells and permit passage of electrical signals or chemicals (i.e., ions and small molecules) from one cell to another



(b) located in some parts of the **nervous system**, in **heart muscle**, and in the **gastrointestinal tract**

Through the connexons, ions and small molecules can diffuse from the cytosol of one cell to another, but the passage of large molecules such as vital intracellular
proteins is prevented.

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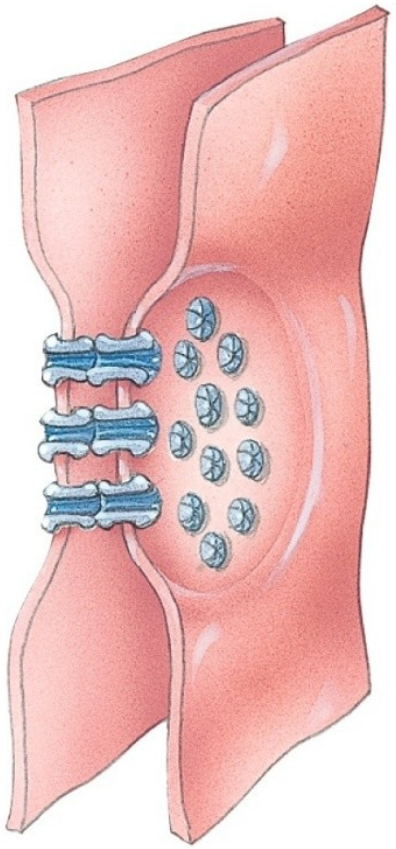
GAP JUNCTIONS

The transfer of nutrients, and perhaps wastes, takes place through gap junctions in avascular tissues such as the lens and cornea of the eye.
Gap junctions allow the cells in a tissue to communicate with one another. In a developing embryo, some of the chemical and electrical signals that regulate growth and cell differentiation travel via gap junctions.



Gap junctions also enable nerve or muscle impulses to spread rapidly among cells, a process that is crucial for the normal operation of some parts of the nervous system and for the contraction of muscle in the heart, gastrointestinal tract, and uterus

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Comparing Epithelial and Connective Tissue

Epithelial Tissue	Connective Tissue
• Many cells tightly packed together with little to no extracellular matrix	• Cells separated by large amounts of extracellular matrix
• NO blood vessels • Always nearby connective tissue (nourishment and excretion of wastes)	• Significant networks of blood vessels
• Form surface layers • Rarely covered by another tissue (exception: blood vessels)	• Can be covered by another tissue

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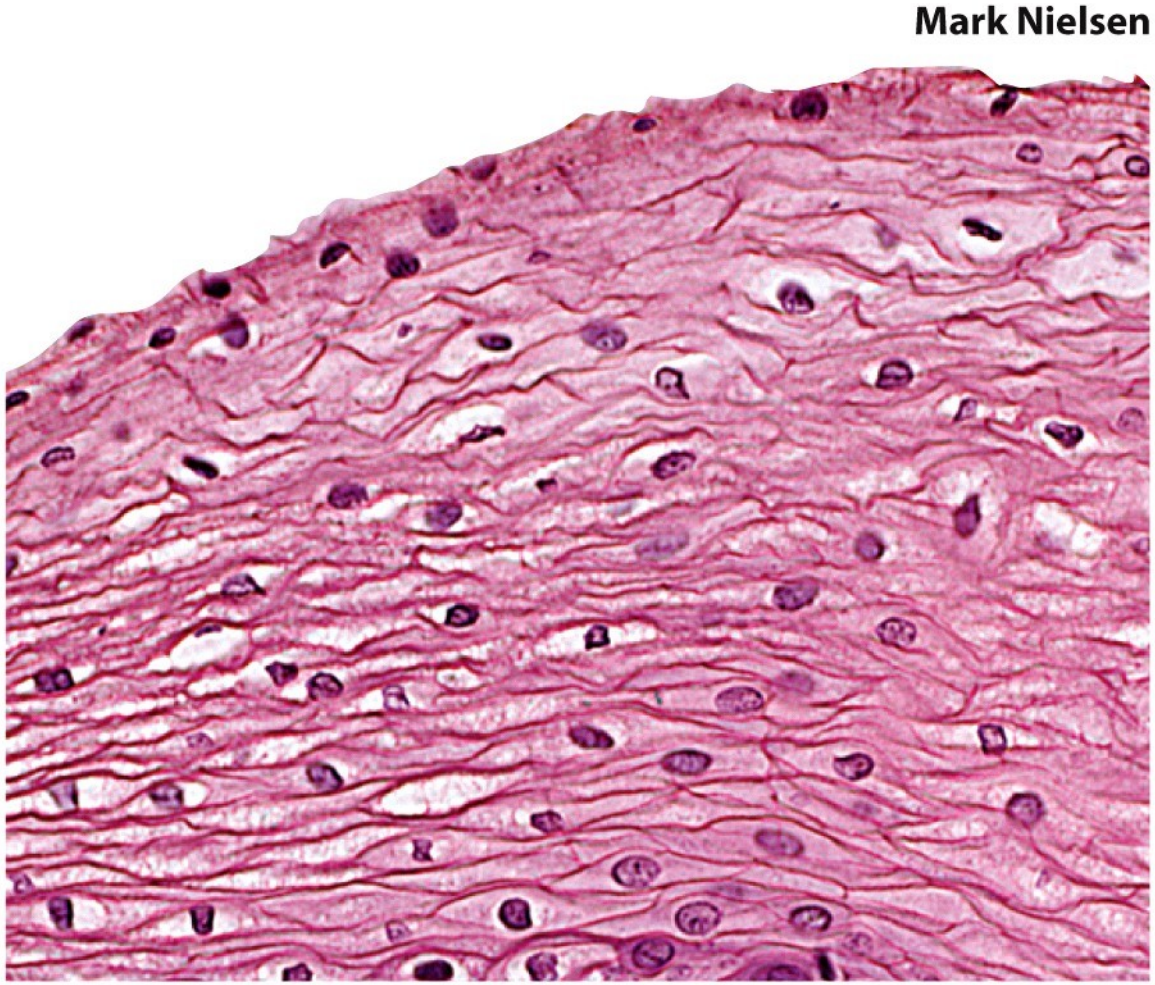

(a) Epithelial tissue with many cells tightly packed together and little to no extracellular matrix

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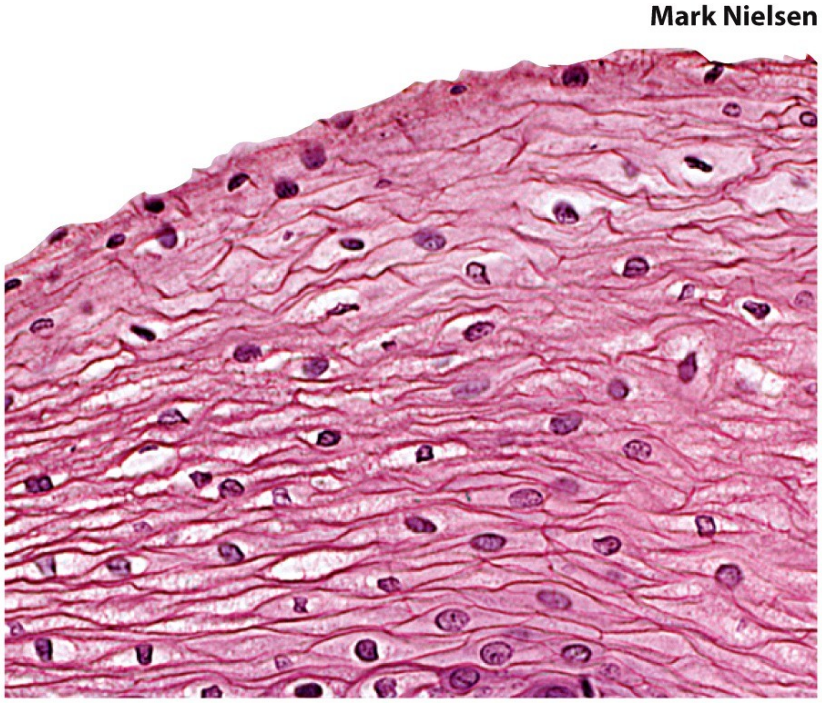
epithelial tissues **always form surface layers** and **are not covered by another tissue**, except within blood vessels where the blood constantly passes over the epithelial tissue lining the vessels.

Epithelial tissues found immediately adjacent to blood-vessel-rich connective tissues, which enable them to make the exchanges with blood necessary for the **delivery of oxygen and nutrients** and the **removal of wastes** that are critical processes for their survival and function.

Epithelial tissue forms **coverings and linings throughout the body**.

It is rarely covered by another tissue, so it **always has a free surface.**



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Mark Nielsen

(b) Connective tissue with a few scattered cells surrounded by large amounts of extracellular matrix

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Epithelial Tissue: General Features

- cells arranged in continuous sheets in either single or multiple layers
- usually closely packed cells with little extracellular material between neighboring cells
- cells have:
  - lateral surfaces
  - apical (free) surface
  - basal surface
- the latter is connected to underlying connective tissue via a thin extracellular **basement membrane**

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Epithelial surfaces

The various surfaces of epithelial cells often differ in structure and have specialized functions.

lateral surfaces face the adjacent cells on either side, may contain tight junctions, adherens junctions, desmosomes, and/or gap junctions.

apical (free) surface faces the body surface, a body cavity, the lumen (interior space) of an internal organ, or a tubular duct that receives cell secretions. Apical surfaces may contain cilia or microvilli.

basal surface is opposite the apical surface.
The basal surfaces of the deepest layer of epithelial cells adhere to extracellular materials such as the basement membrane.
Hemidesmosomes in the basal surfaces of the deepest layer of epithelial cells anchor the epithelium to the basement membrane

FYI In discussing epithelia with multiple layers the term *apical layer* refers to the most superficial layer of cells, and the *basal layer* is the deepest layer of cells.

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Basement Membranes - Structure

thin extracellular layer consists of two layers:

basal lamina

- closer to and secreted by the epithelial cells
- contains proteins such as laminin, collagen, glycoproteins and proteoglycans
- laminin molecules in the basal lamina adhere to integrins in hemidesmosomes and thus attach epithelial cells to the basement membrane

reticular lamina

- closer to the underlying connective tissue
- contains proteins such as collagen produced by connective tissue cells called *fibroblasts*

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Basement Membranes - Function

- attach to and support the overlying epithelial tissue
- form a surface along which epithelial cells migrate during growth or wound healing
- restrict passage of larger molecules between epithelium and connective tissue
- participate in filtration of blood in the kidneys

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Basement Membranes and Disease

Can become markedly thickened, due to increased production of collagen and laminin.

Diabetes mellitus (untreated cases):
the basement membrane of small blood vessels (capillaries) thickens especially in the eyes and kidneys

⇒ improper function of blood vessels

⇒ blindness and kidney failure

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Epithelial Tissue: General Features

- numerous cell junctions that securely attach neighboring cells
- avascular tissue that exchanges materials with adjacent connective tissue via diffusion
- has own nerve supply
- high capacity for cell division in order to replace cells lost due to wear and tear and injury
- numerous functions including:
  - protection, filtration, secretion, absorption, excretion
- combines with nervous tissue to form special organs for smell, hearing, vision, and touch

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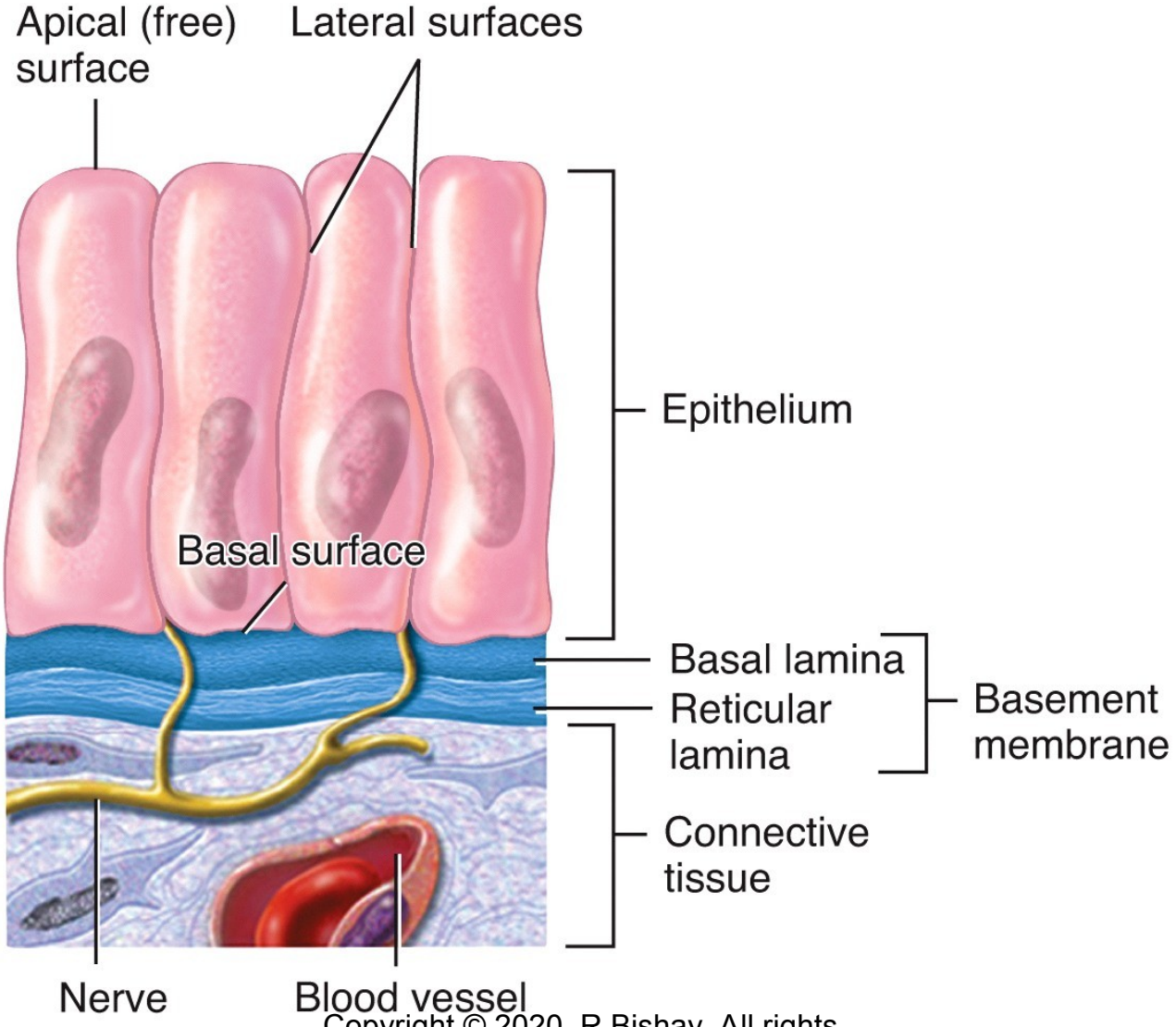
Surface of Epithelial Cells



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Repeatedly subjected to physical stress and injury (boundaries between organs or external environments) cell division allows epithelial tissue to constantly renew and repair itself by sloughing off dead or injured cells and replacing them with new ones

Protection against the abrasive influences of the environment

Filtration serve as selective barriers to limit or aid the transfer of substances into and out of the body

Absorption is the intake of fluids or other substances such as digested food from the intestinal tract.

Secretion is the production and release of substances such as mucus, sweat, or enzymes onto their free surfaces

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Anatomy Overview:

- Epithelial Tissues

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Epithelial Tissue: 2 Types

- **Covering and lining epithelium**
  - forms *outer* covering of skin and some internal organs
  - forms *inner* lining of blood vessels, ducts, and body cavities, and the interior of the respiratory, digestive, urinary, and reproductive systems
- **Glandular epithelium**
  - makes up secreting portion of glands such as the thyroid gland, adrenal glands, and sweat glands.

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Glandular epithelium

Protection against the abrasive influences of the environment

Filtration serve as selective barriers to limit or aid the transfer of substances into and out of the body

Absorption is the intake of fluids or other substances such as digested food from the intestinal tract.

Secretion is the production and release of substances such as mucus, sweat, or enzymes onto their free surfaces

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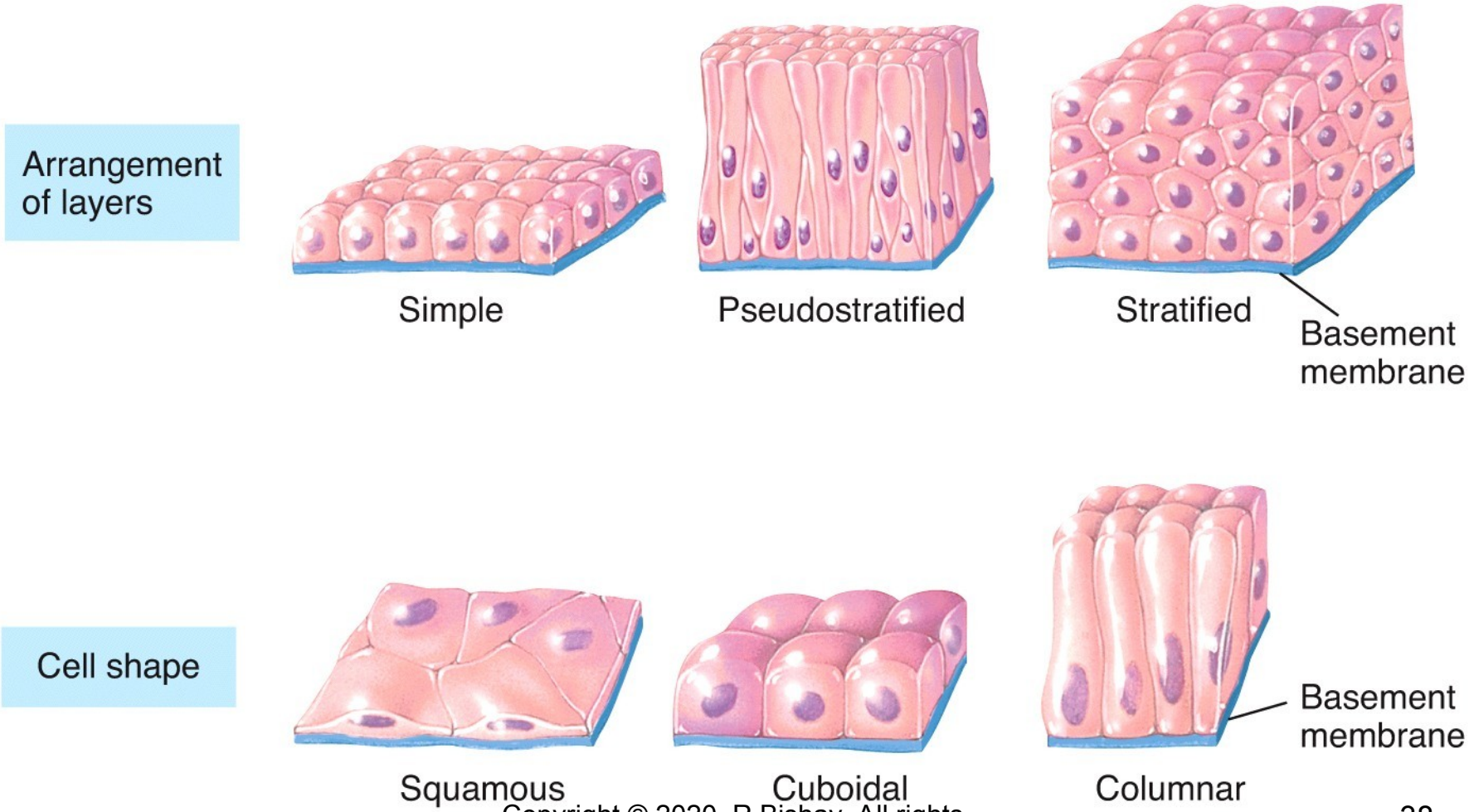
Covering and Lining Epithelium: Arrangement of Layers and Cell Shapes



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Covering and Lining Epithelium: Classification

Arrangement of cells into layers reflects its location and function

- **Simple (unilaminar) epithelium** (single layer of cells)
- **Pseudostratified epithelium** (single layer that appears stratified)
- **Stratified (multilaminar) epithelium** (two + cell layers)

Cells may be categorized by cell shape

- **Squamous** cells are flattened
- **Cuboidal** cells are usually cube-shaped or hexagons
- **Columnar** cells are tall and cylindrical
- **Transitional** cells are able to undergo changes in shape caused by distension

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Covering and Lining Epithelium: Classification

Epithelium may be classified according to number of layers present AND *cell shapes (in the apical layer)*

Simple epithelium

- Simple squamous epithelium
- Simple cuboidal epithelium
- Simple columnar epithelium (nonciliated and ciliated)
- Pseudostratified columnar epithelium (nonciliated and ciliated)

Stratified epithelium

- Stratified squamous epithelium (keratinized, when surface cells are dead and become hardened, and nonkeratinized, when surface cells remain alive)*
- Stratified cuboidal epithelium*
- Stratified columnar epithelium*
- Transitional epithelium

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Epithelial Tissues

TABLE 3.1

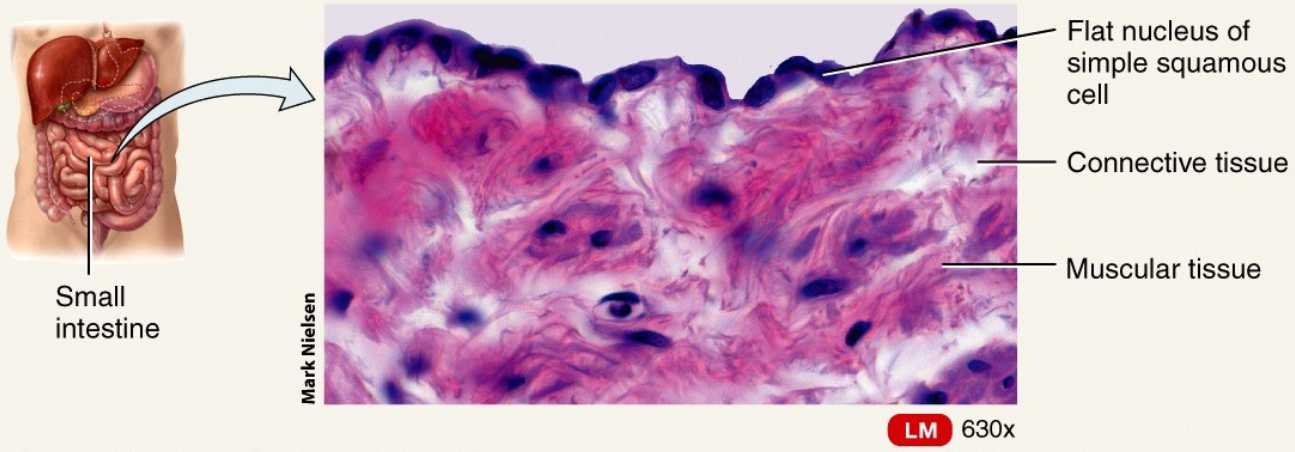
Epithelial Tissue: Covering and Lining Epithelium

A. SIMPLE SQUAMOUS EPITHELIUM

Description: Single layer of flat cells that resembles a tiled floor when viewed from the apical surface; centrally located nucleus that is flattened and oval or spherical in shape.

Location: Occurs in two common locations in the body. The simple squamous epithelium that lines the cardiovascular and lymphatic system, that is, the heart, blood vessels, and lymphatic vessel linings, is known as **endothelium** (en′-dō-THĒ-lē-um; *endo-*=within; *-thelium*=covering). The simple squamous epithelium that forms the **epithelial** layer of serous membranes, such as the peritoneum, pleura, or pericardium, is called **mesothelium** (mez′-ō-THĒ-lē-um; *meso-*=middle). It is also found in the air sacs of lungs, glomerular (Bowman's) capsule of kidneys, and inner surface of the tympanic membrane (eardrum).

Function: Present at sites where the processes of filtration (such as blood filtration in the kidneys), diffusion (such as diffusion of oxygen into blood vessels of the lungs), and secretion (in serous membrane) occur. It is not found in body areas that are subject to mechanical stress (wear and tear).



Sectional view of simple squamous epithelium (mesothelium) of peritoneum of small intestine

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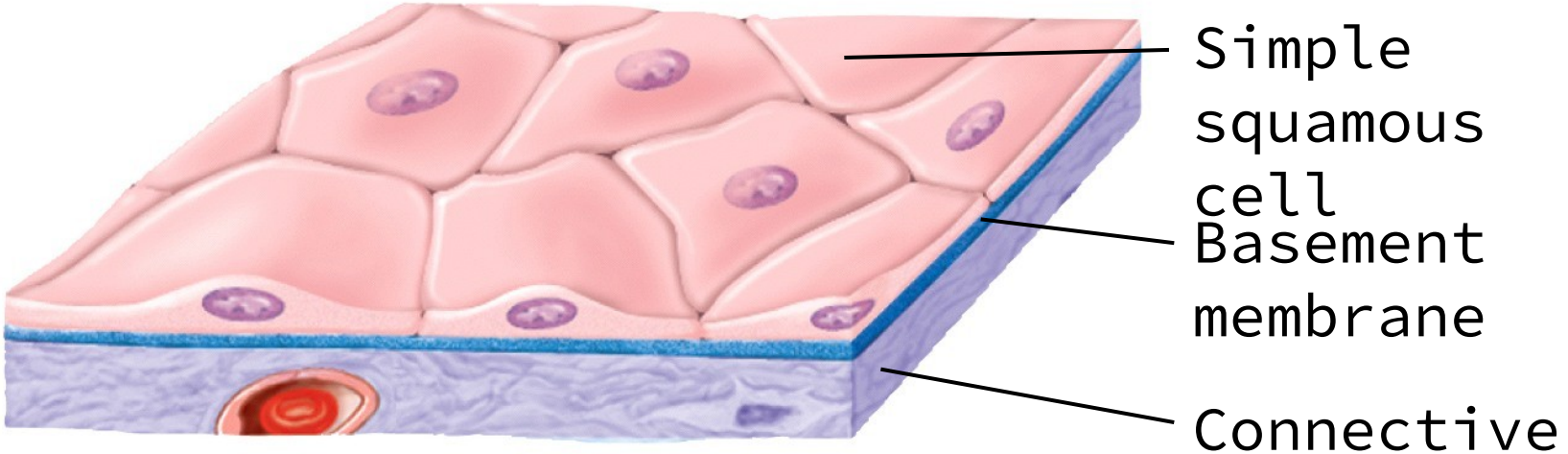

Simple squamous epithelium

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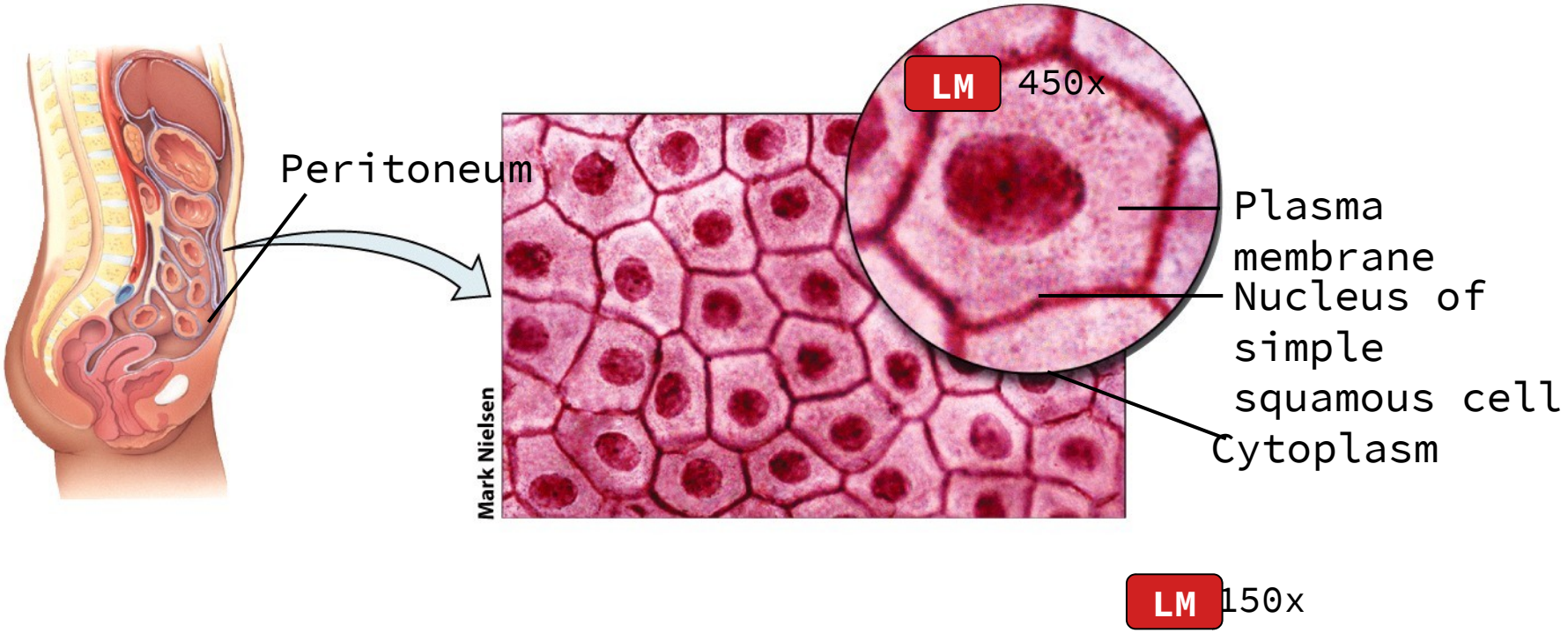

Surface view of simple squamous epithelium of mesothelial lining of peritoneum

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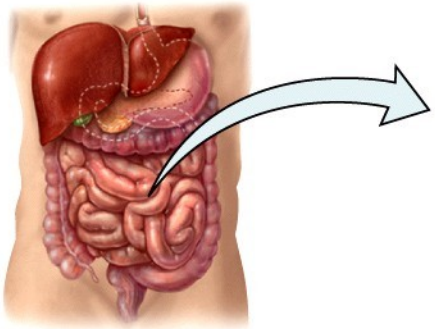
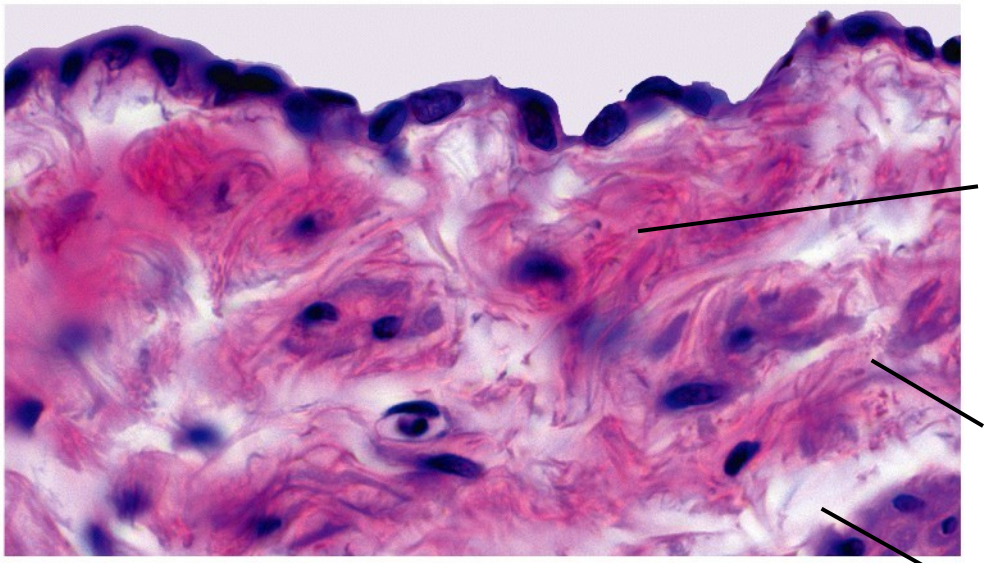


Small intestine



Sectional view of simple squamous epithelium (mesothelium) of peritoneum of small intestine

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Simple Cuboidal

TABLE 3.1

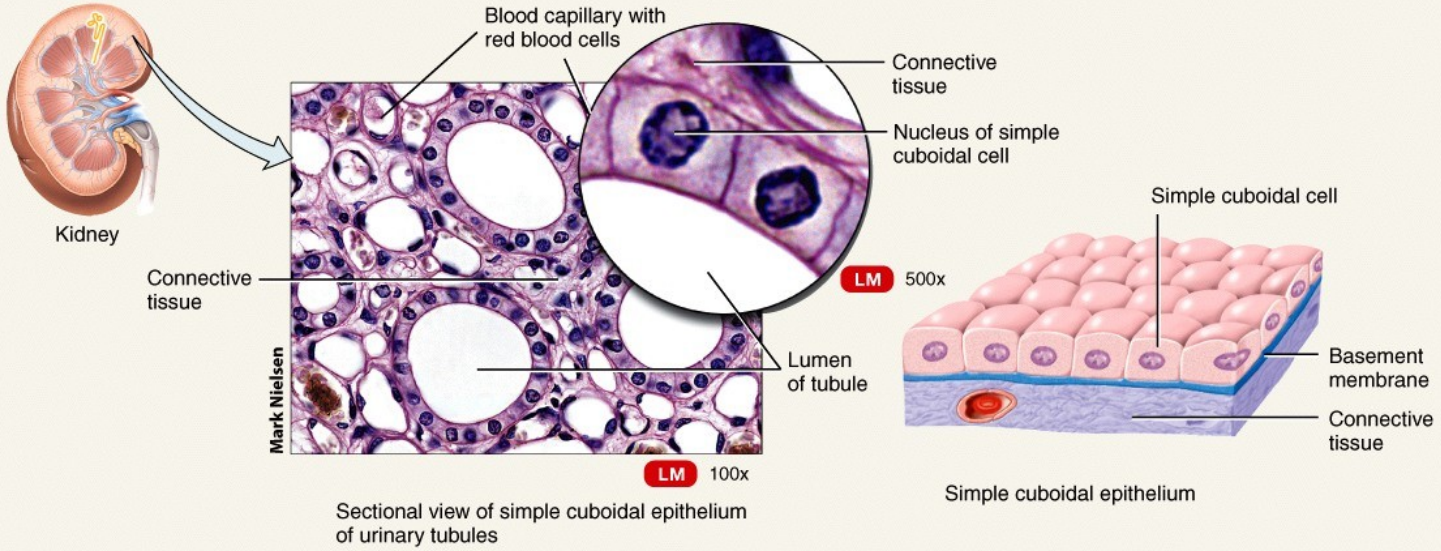
Epithelial Tissue: Covering and Lining Epithelium

B. SIMPLE CUBOIDAL EPITHELIUM

Description: Single layer of cube-shaped cells; round, centrally located nucleus. The cuboidal shape of the cells in simple cuboidal epithelium is obvious when the tissue is sectioned and viewed from the side. Note that cells that are strictly cuboidal could not form small tubes; such cuboidal cells are more pie-shaped but they are still nearly as high as they are wide (at the base).

Location: Covers surface of ovary, lines anterior surface of capsule of the lens of the eye, forms the pigmented epithelium at the posterior surface of the retina of the eye, lines kidney tubules and smaller ducts of many glands, and makes up the secretory portion of some glands such as the thyroid gland and the ducts of some glands such as the pancreas.

Function: Secretion and absorption.



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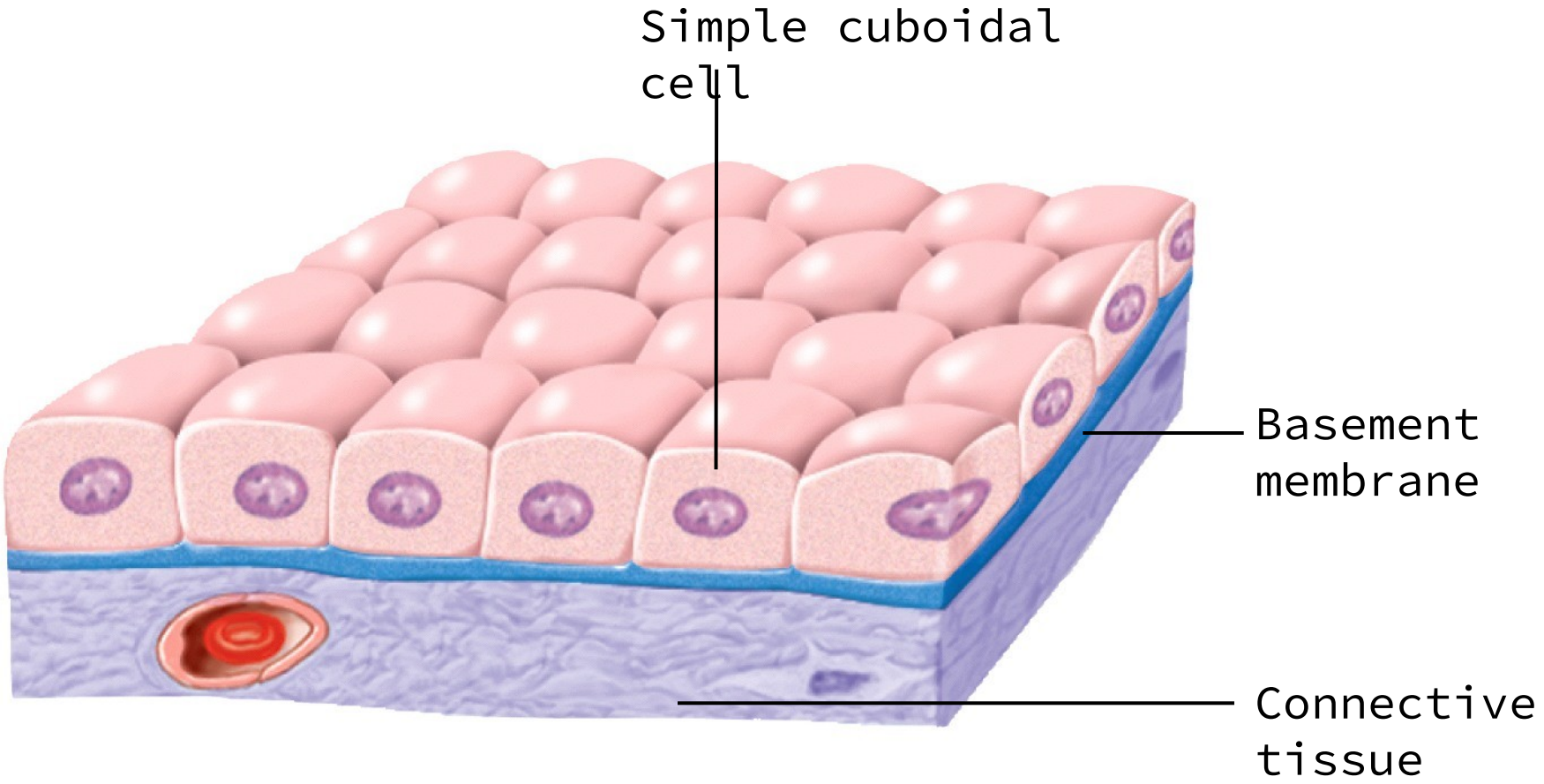

Simple cuboidal epithelium

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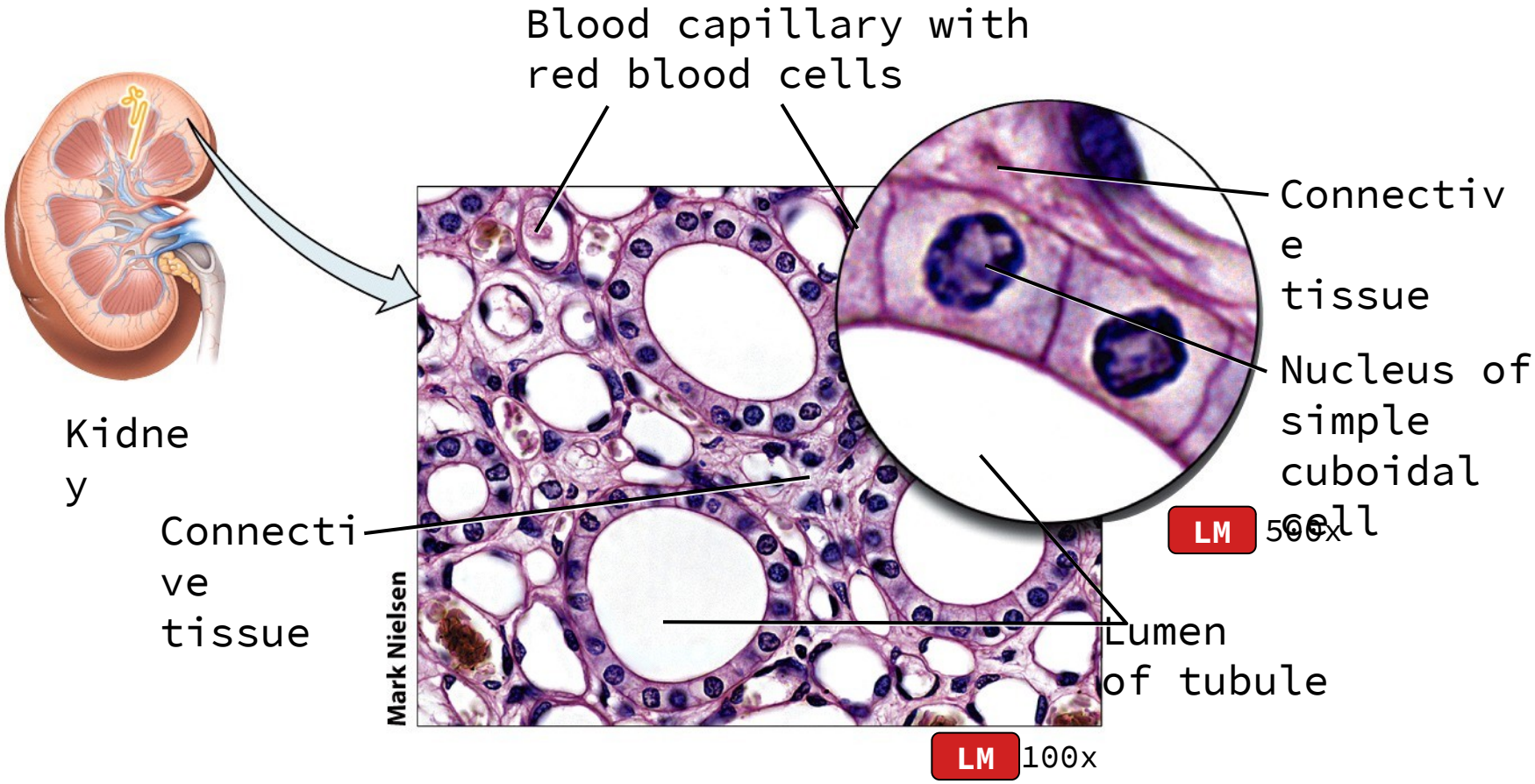

Sectional view of simple cuboidal epithelium of tubules

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Nonciliated Simple Columnar Epithelium

TABLE 3.1

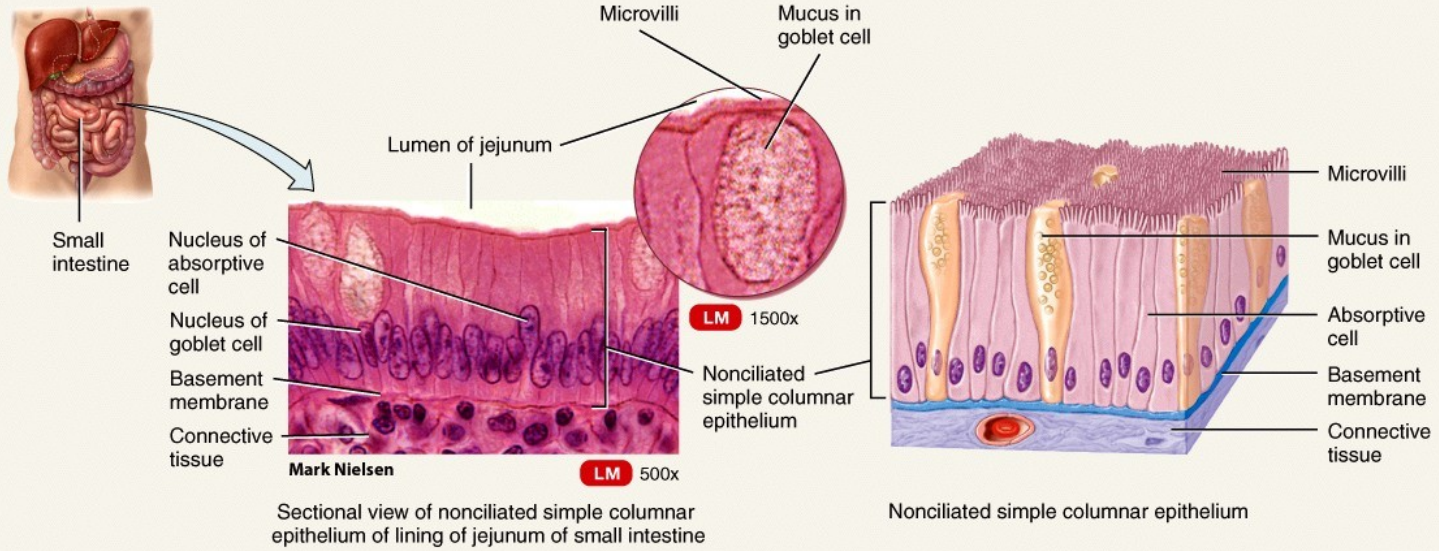
Epithelial Tissue: Covering and Lining Epithelium

C. NONCILIATED SIMPLE COLUMNAR EPITHELIUM

Description: Single layer of nonciliated column-like cells with oval nuclei near base of cells; contains two types of cells—columnar epithelial cells with microvilli at their apical surface, and goblet cells. **Microvilli**, fingerlike cytoplasmic projections, increase the surface area of the plasma membrane (see Figure 2.1), thus increasing the rate of absorption by the cell. **Goblet cells** are modified columnar epithelial cells that secrete mucus, a slightly sticky fluid, at their apical surfaces. Before it is released, mucus accumulates in the upper portion of the cell, causing it to bulge out and making the whole cell resemble a goblet or wine glass.

Location: Lines the gastrointestinal tract (from the stomach to the anus), ducts of many glands, and gallbladder.

Function: Secretion and absorption, but the larger columnar cells contain more organelles and are therefore capable of a higher level of secretion and absorption than are cuboidal cell. Secreted mucus serves as a lubricant for the linings of the digestive, respiratory, and reproductive tracts, and most of the urinary tract. Mucus also helps prevent destruction of the stomach lining by acidic gastric juice secreted by the stomach.



Sectional view of nonciliated simple columnar epithelium of lining of jejunum of small intestine

Nonciliated simple columnar epithelium

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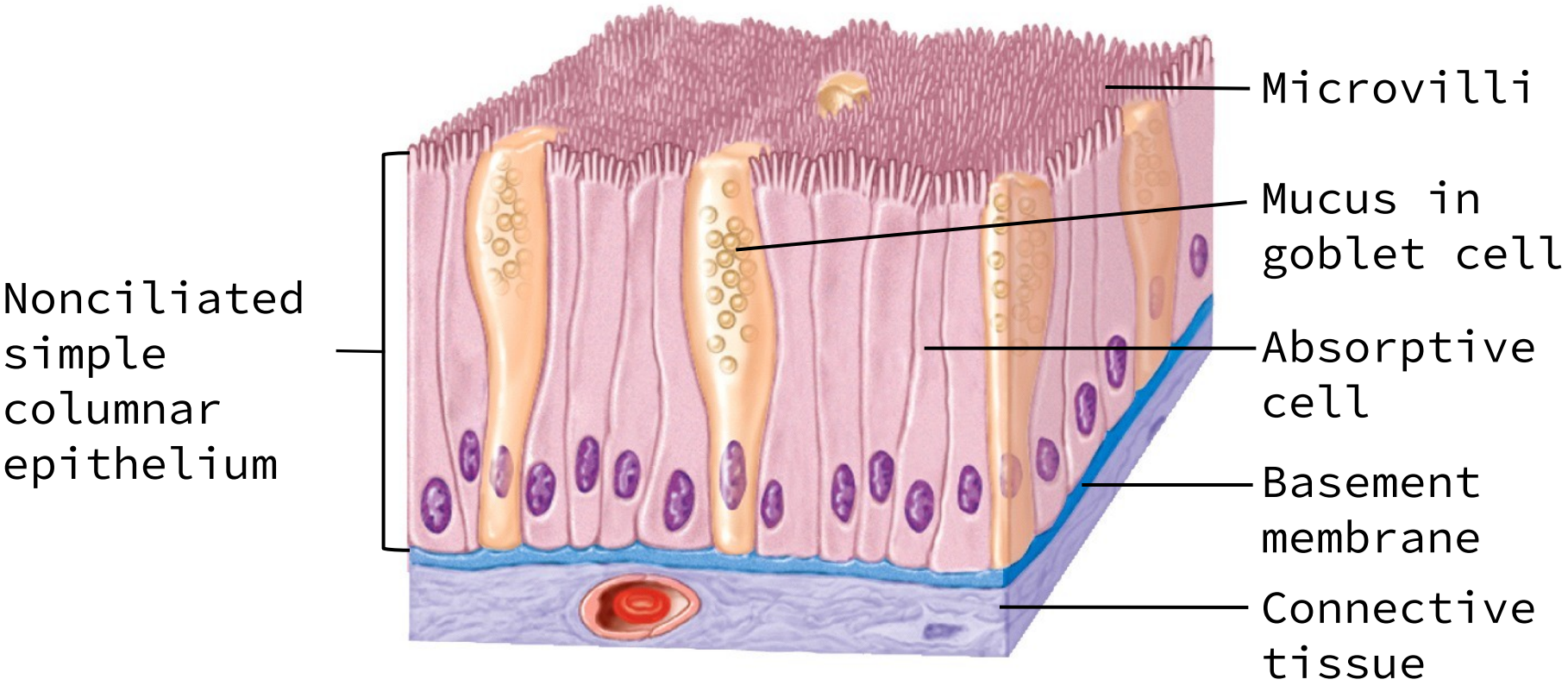

Nonciliated simple columnar epithelium

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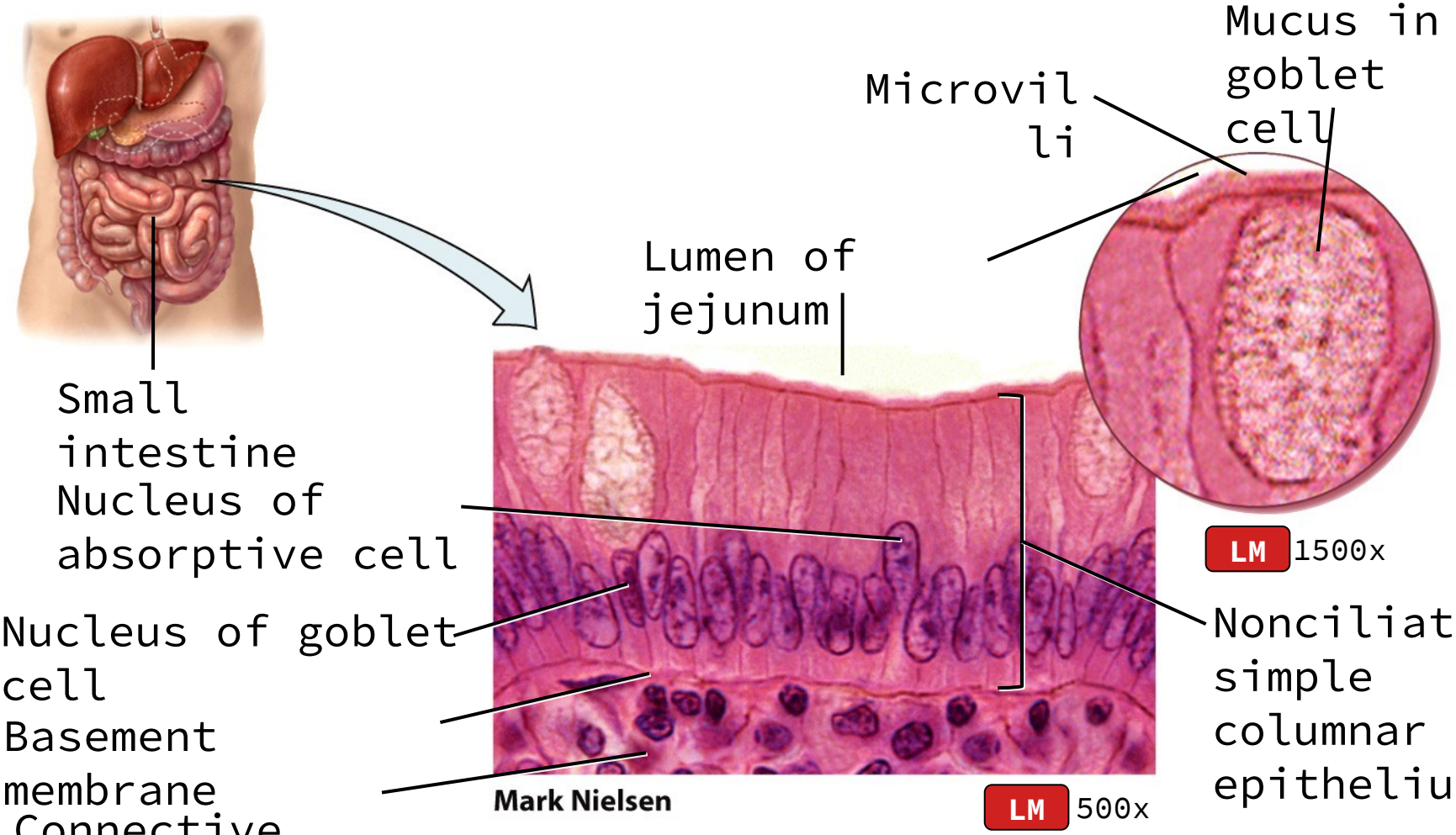

Sectional view of nonciliated simple columnar epithelium of lining of jejunum intestine

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Ciliated Simple Columnar Epithelium

TABLE 3.1

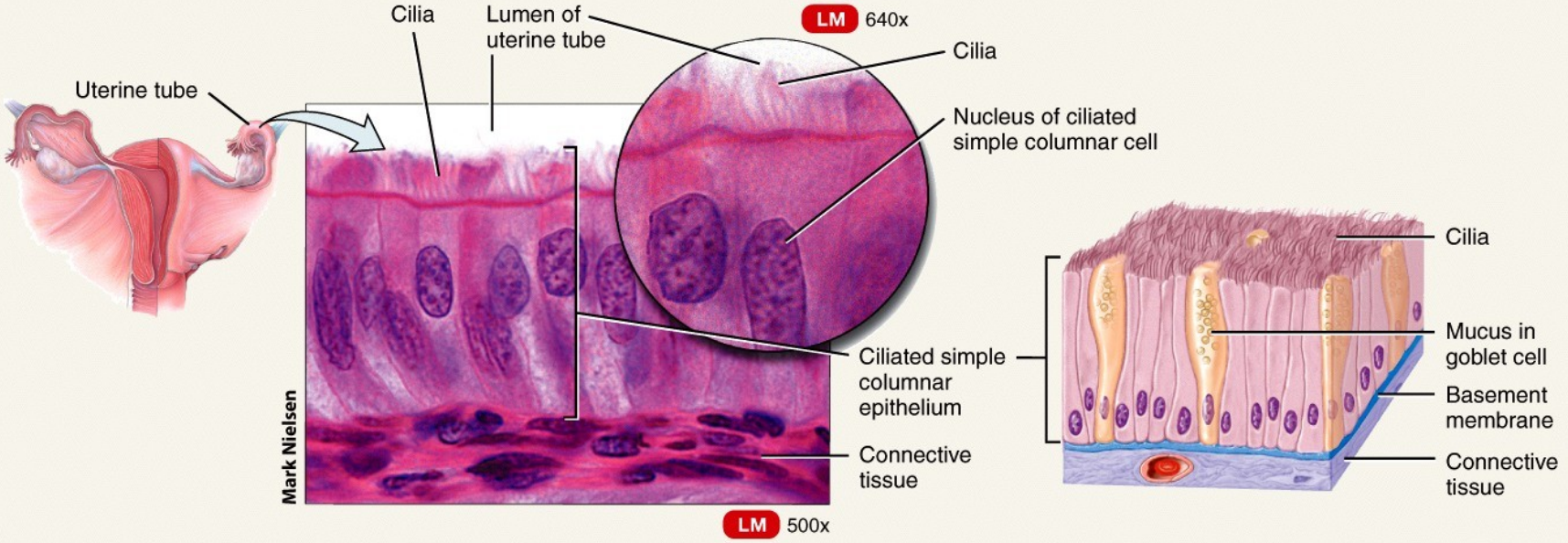
Epithelial Tissue: Covering and Lining Epithelium

D. CILIATED SIMPLE COLUMNAR EPITHELIUM

Description: Single layer of ciliated column-like cells with oval nuclei near base of cells. In certain parts of the smaller airways of the upper respiratory tract, goblet cells are interspersed among ciliated columnar epithelia.

Location: Lines some bronchioles (small tubes) of respiratory tract, uterine (fallopian) tubes, uterus, some paranasal sinuses, central canal of spinal cord, and ventricles of the brain.

Function: The cilia beat in unison, moving the mucus and any foreign particles toward the throat, where they can be coughed up and swallowed or spit out. Coughing and sneezing speed up the movement of cilia and mucus. Cilia also help move oocytes expelled from the ovaries through the uterine (fallopian) tubes into the uterus.



Sectional view of ciliated simple columnar epithelium of uterine tube

Ciliated simple columnar epithelium

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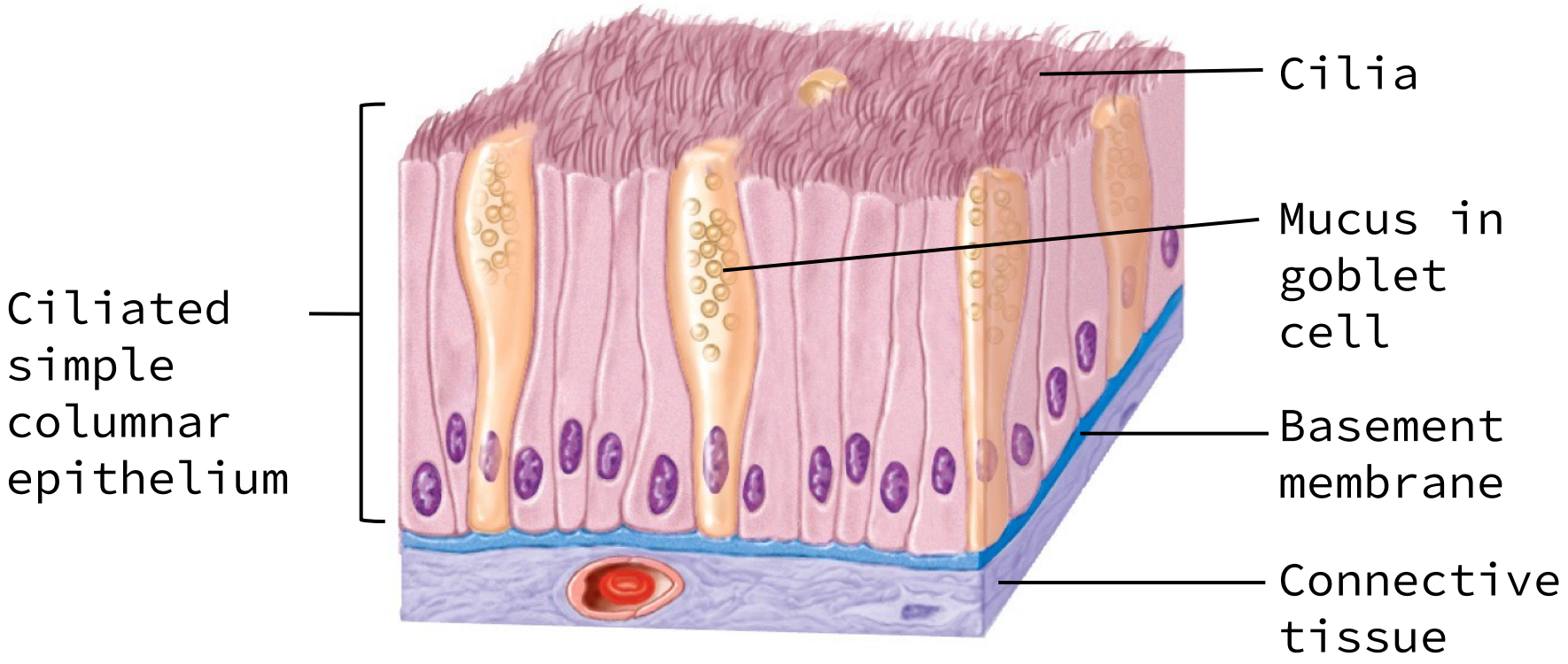

Ciliated simple columnar epithelium

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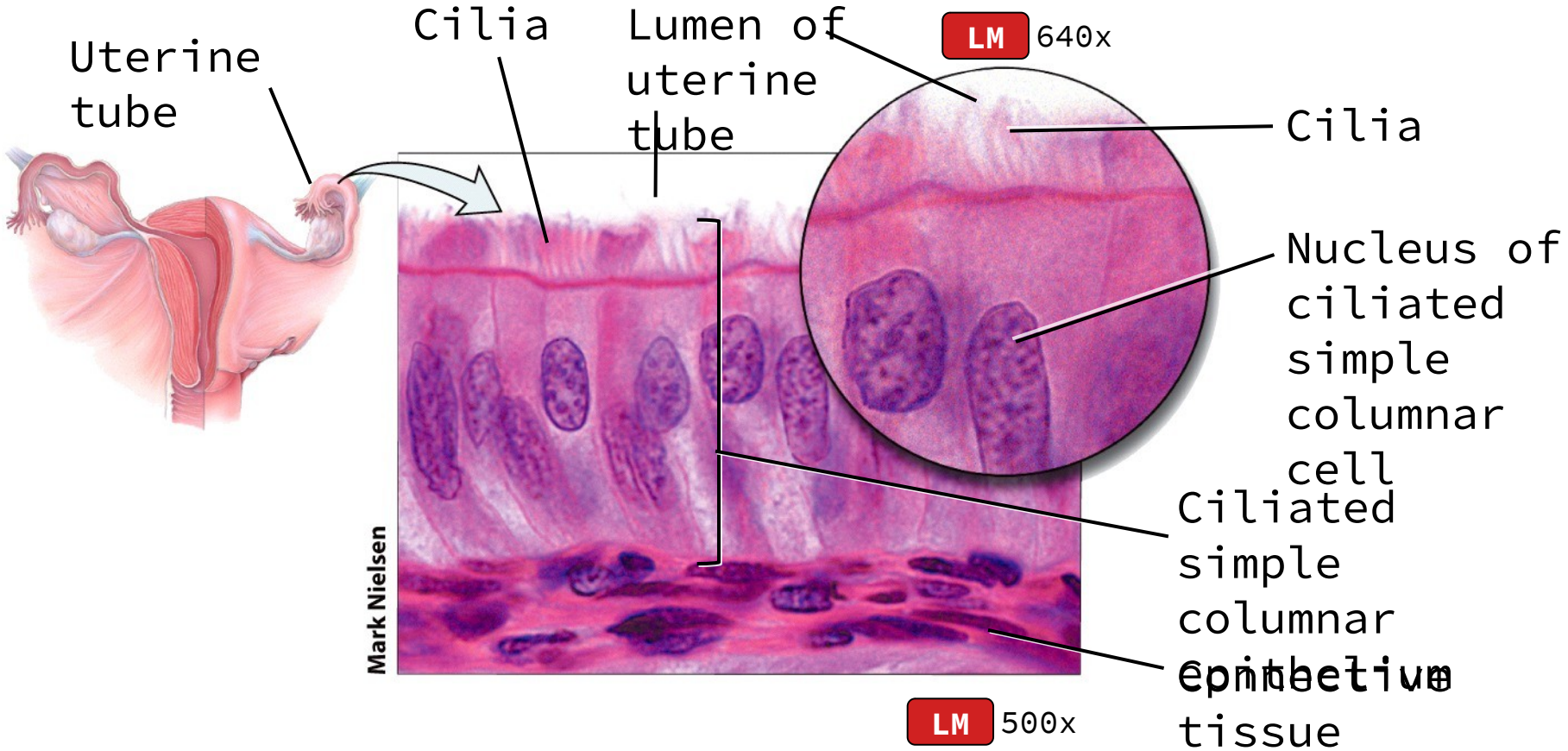

Sectional view of ciliated simple columnar
ne tube

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Pseudostratified Columnar

TABLE 3.1

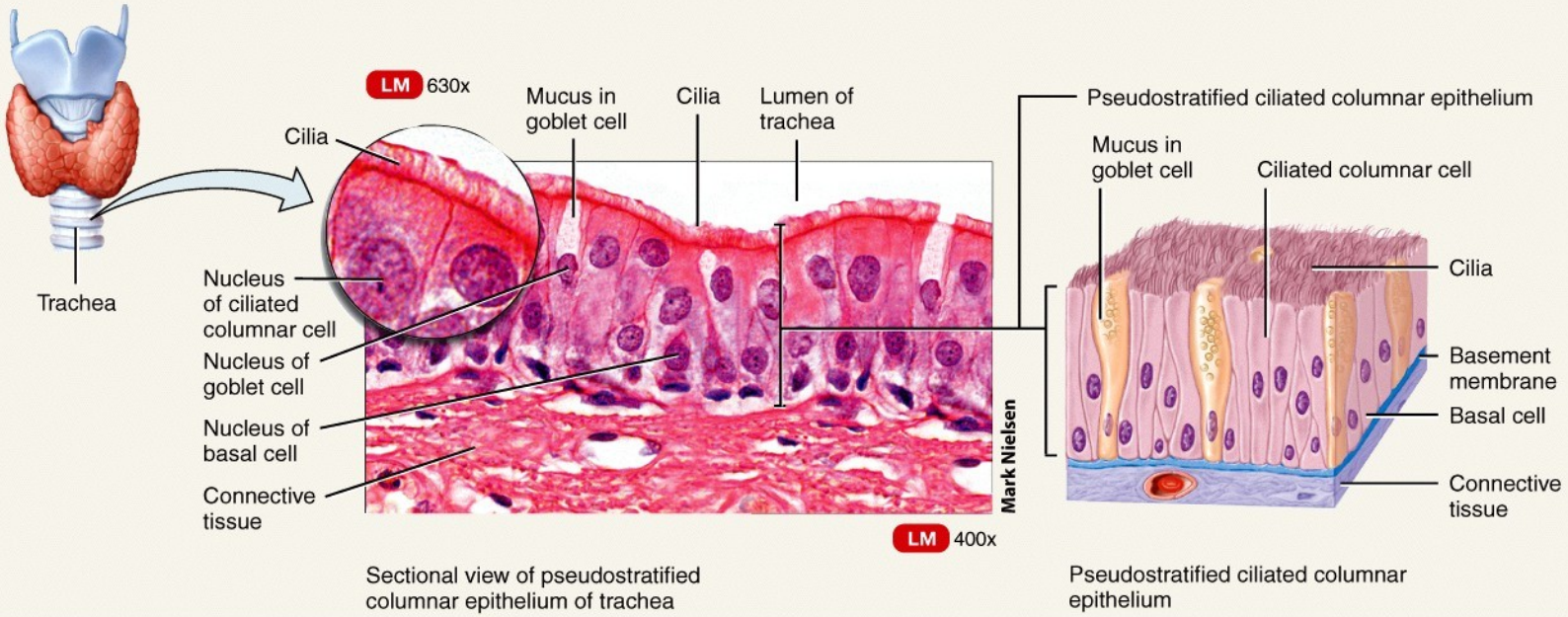
Epithelial Tissue: Covering and Lining Epithelium

E. PSEUDOSTRATIFIED COLUMNAR EPITHELIUM

Description: Appears to have several layers because the nuclei of the cells are at various levels. Even though all the cells are attached to the basement membrane in a single layer, some cells do not extend to the apical surface. When viewed from the side, these features give the false impression of a multilayered tissue—thus the name pseudostratified epithelium (*pseudo-*=false). *Pseudostratified ciliated columnar epithelium* contains cells that extend to the surface and either secrete mucus (goblet cells) or bear cilia. *Pseudostratified nonciliated columnar epithelium* contains cells without cilia and also lacks goblet cells.

Location: Pseudostratified ciliated columnar epithelium lines the airways of most of the upper respiratory tract; pseudostratified nonciliated columnar epithelium lines larger ducts of many glands, epididymis, and part of male urethra.

Function: Pseudostratified ciliated columnar epithelium secretes mucus that traps foreign particles, and the cilia sweep away the mucus for eventual elimination from the body. Pseudostratified nonciliated columnar epithelium functions in absorption and protection.



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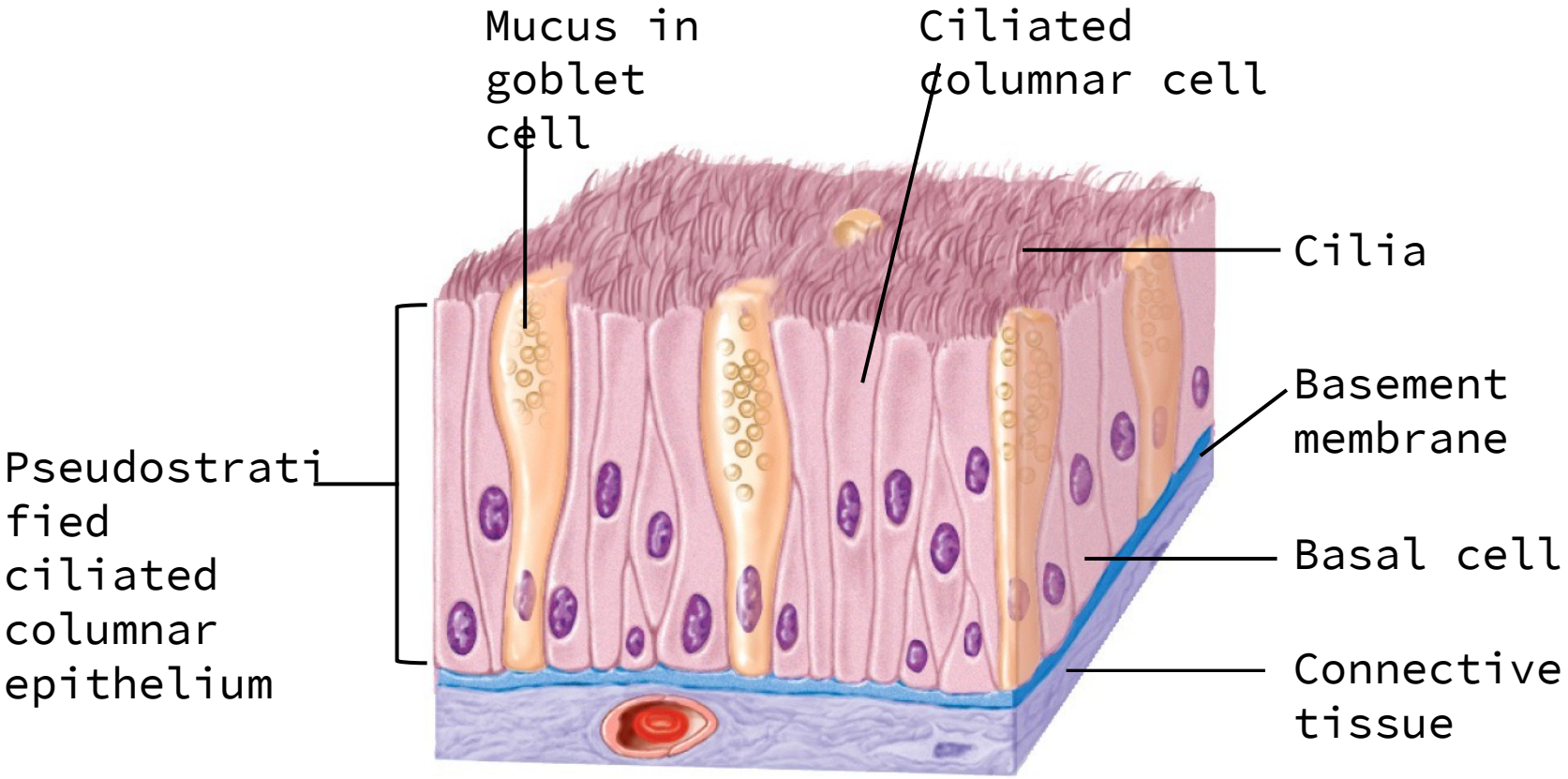

Pseudostratified ciliated columnar epithelium

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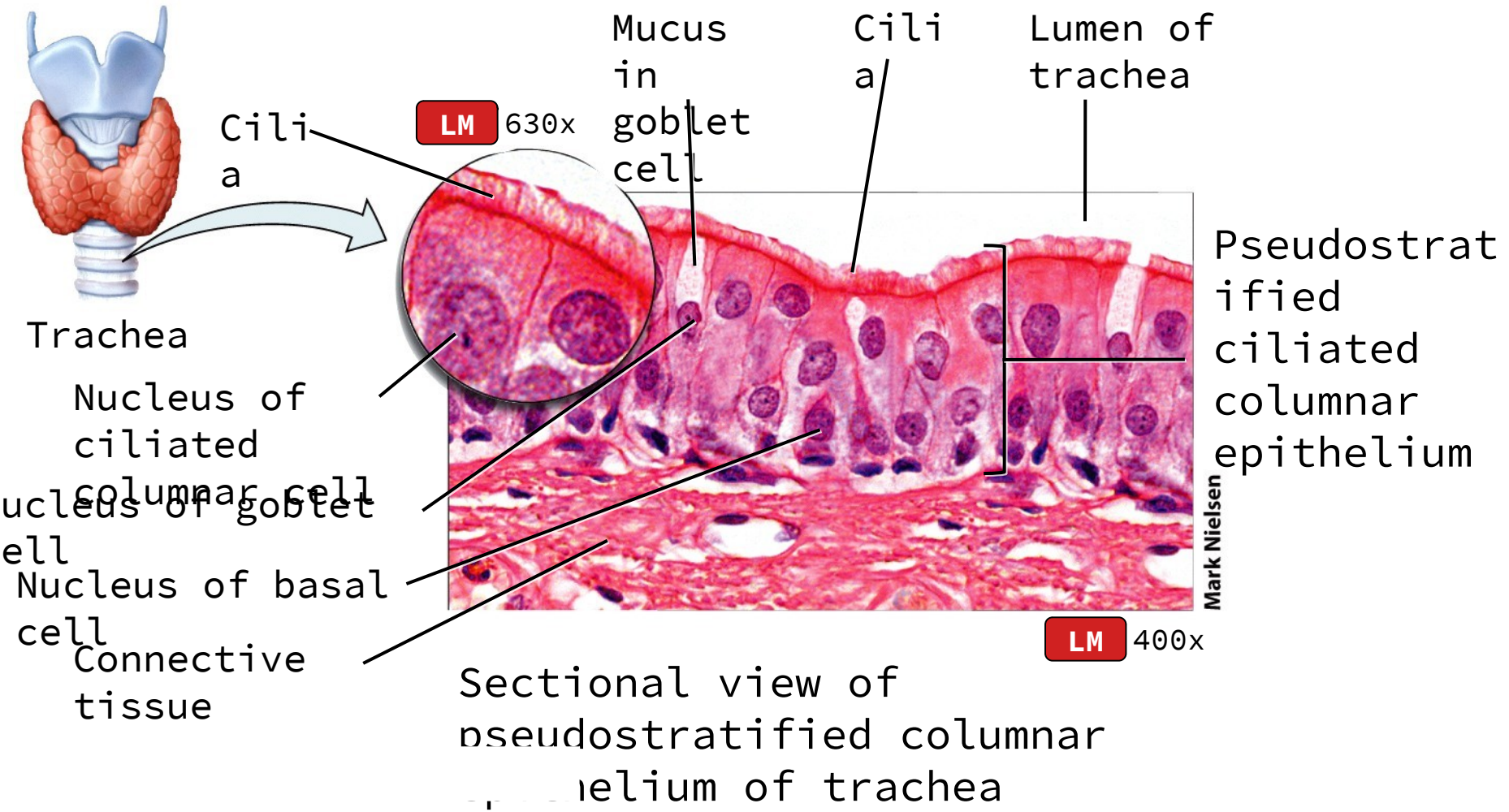

Sectional view of pseudostratified columnar epithelium of trachea

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Stratified Epithelial Tissues

- Stratified squamous
- Stratified cuboidal
- Stratified columnar
- Transitional

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Stratified Squamous Epithelium

TABLE 3.1

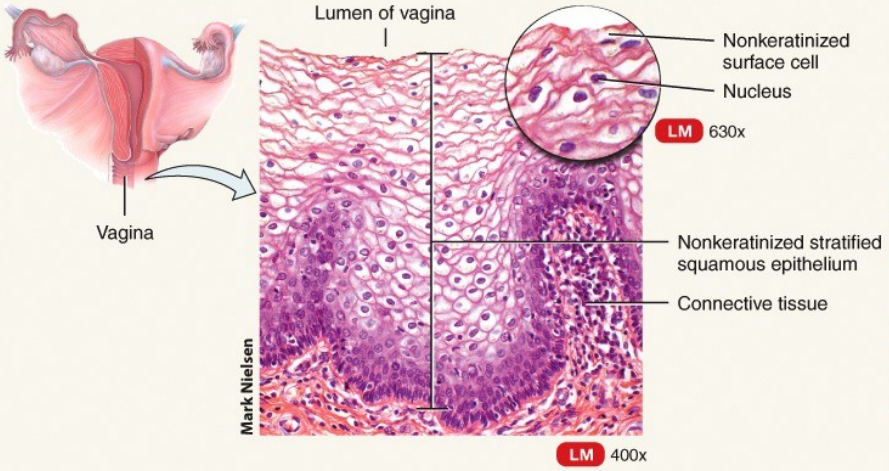
Epithelial Tissue: Covering and Lining Epithelium

F. STRATIFIED SQUAMOUS EPITHELIUM

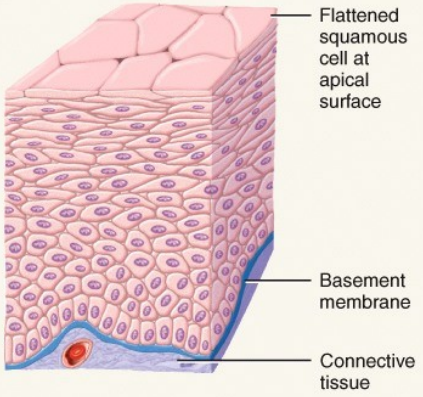
Description: Consists of two or more layers of cells; cells in the apical layer and several layers deep to it are squamous; cells in the deeper layers vary from cuboidal to columnar. As basal cells divide, cells arising from the cell divisions push upward toward the apical layer. As they move toward the surface and away from their blood supply in the underlying connective tissue, they become dehydrated and less metabolically active as they shrink in size. As their cytoplasm is reduced, the percentage of tough proteins predominate within the cell and they become tough, hard structures that eventually die. At the apical layer, after the dead cells lose their cell junctions they are sloughed off, but they are replaced continuously as new cells emerge from the basal cells. Stratified squamous epithelium exists in both keratinized and nonkeratinized forms. *Keratinized stratified squamous epithelium* develops a tough layer of keratin in the apical layer of cells and several cell layers deep to it (see Figure 5.3). **Keratin** is a tough, fibrous intracellular protein that helps protect the skin and underlying tissues from heat, microbes, and chemicals. The relative amount of keratin increases in the cells as they move away from their nutritive blood supply and the organelles die. *Nonkeratinized stratified squamous epithelium* does not contain large amounts of keratin in the apical layer and several layers deep to it and is constantly moistened by mucus secreted from salivary and mucous glands. The organelles are not replaced in this epithelium.

Location: Keratinized variety forms superficial layer of skin; nonkeratinized variety lines wet surfaces, such as lining of the mouth, esophagus, part of epiglottis, part of pharynx, and vagina, and covers the tongue.

Function: Protection against abrasion, water loss, ultraviolet radiation, and foreign invasion. Both types of stratified squamous epithelium form the first line of defense against microbes.



Sectional view of nonkeratinized stratified squamous epithelium of lining of vagina



Nonkeratinized stratified squamous epithelium

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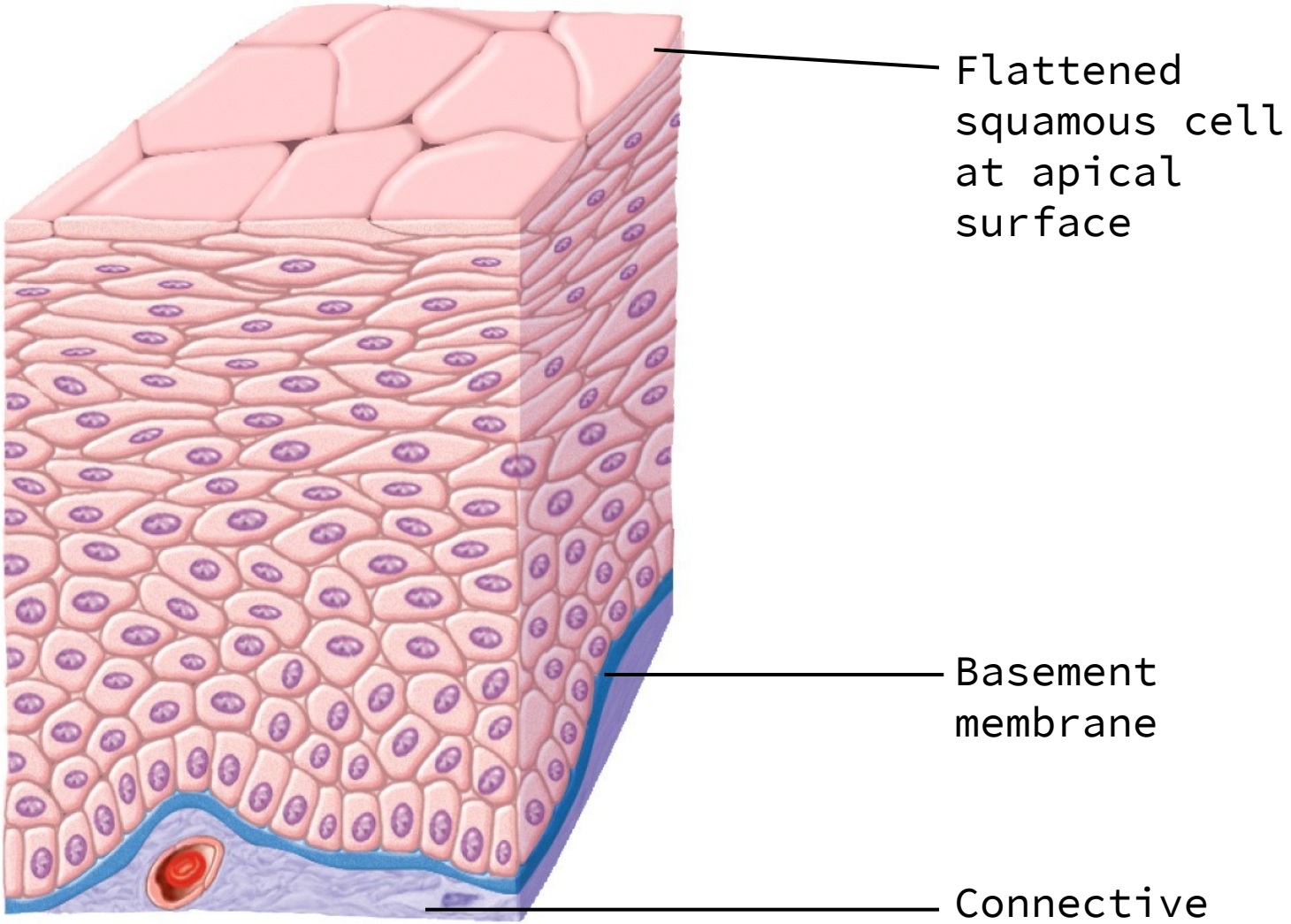

Nonkeratinized stratified squamous epithelium

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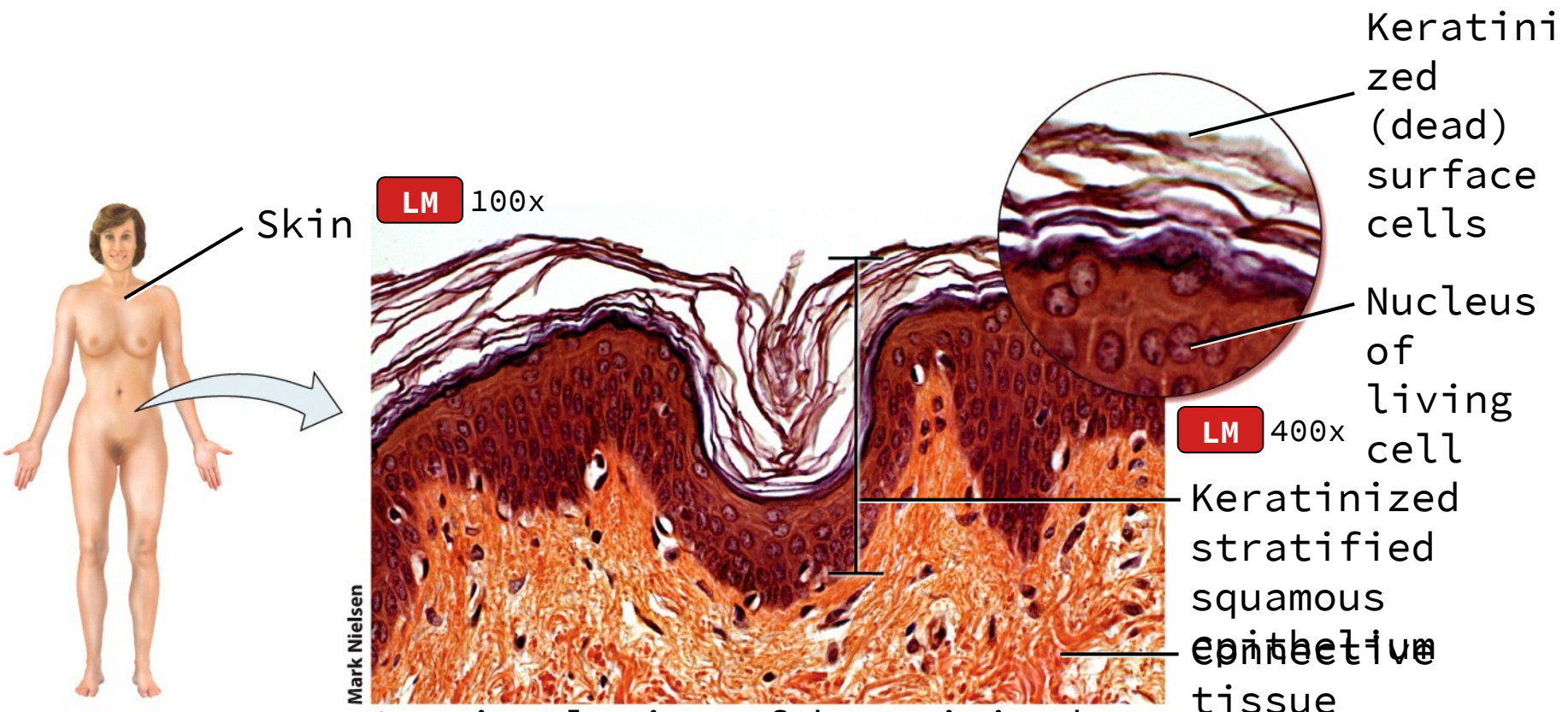

Sectional view of keratinized stratified squamous epithelium of

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Epidermis:

Location of four principal cell types in thick skin

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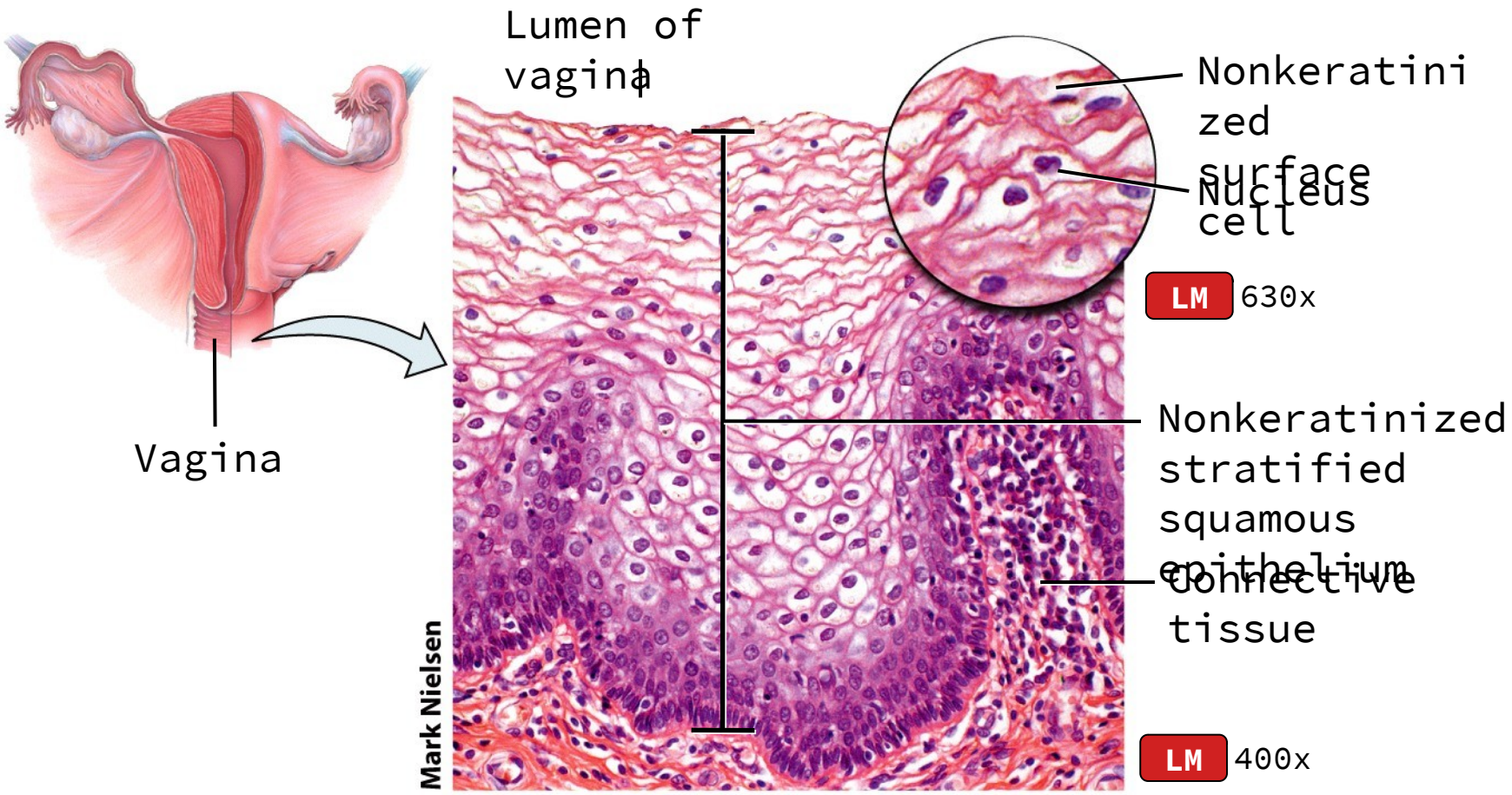

Sectional view of nonkeratinized stratified squamous epithelium of vagina

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Stratified Cuboidal Epithelium

TABLE 3.1

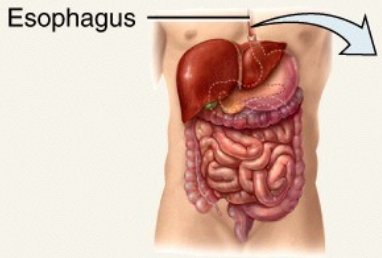
Epithelial Tissue: Covering and Lining Epithelium

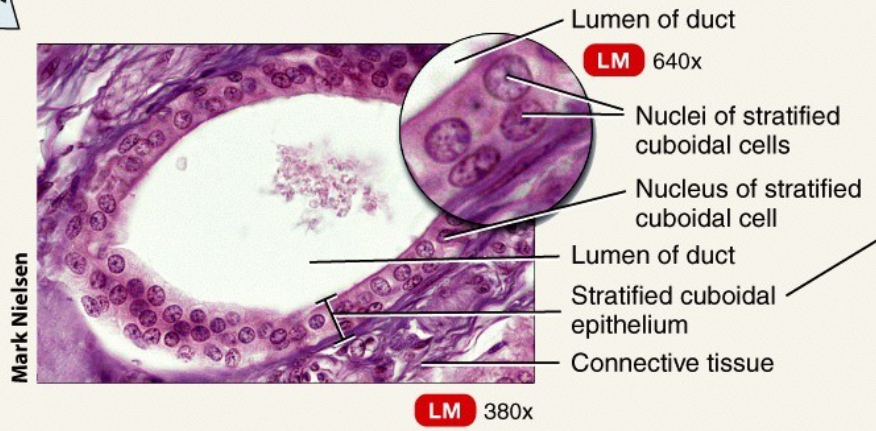
G. STRATIFIED CUBOIDAL EPITHELIUM

Description: Two or more layers of cells in which the cells in the apical layer are cube-shaped. This is a fairly rare type of epithelium.

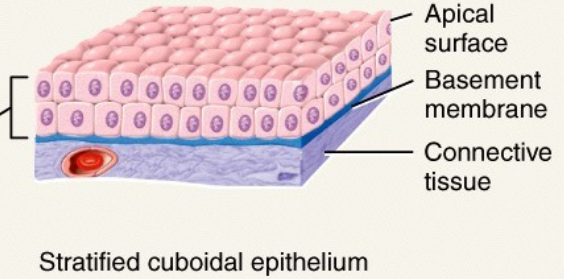
Location: Ducts of adult sweat glands and esophageal glands and part of male urethra.

Function: Protection and limited secretion and absorption.





Sectional view of stratified cuboidal epithelium of the duct of an esophageal gland



Stratified cuboidal epithelium

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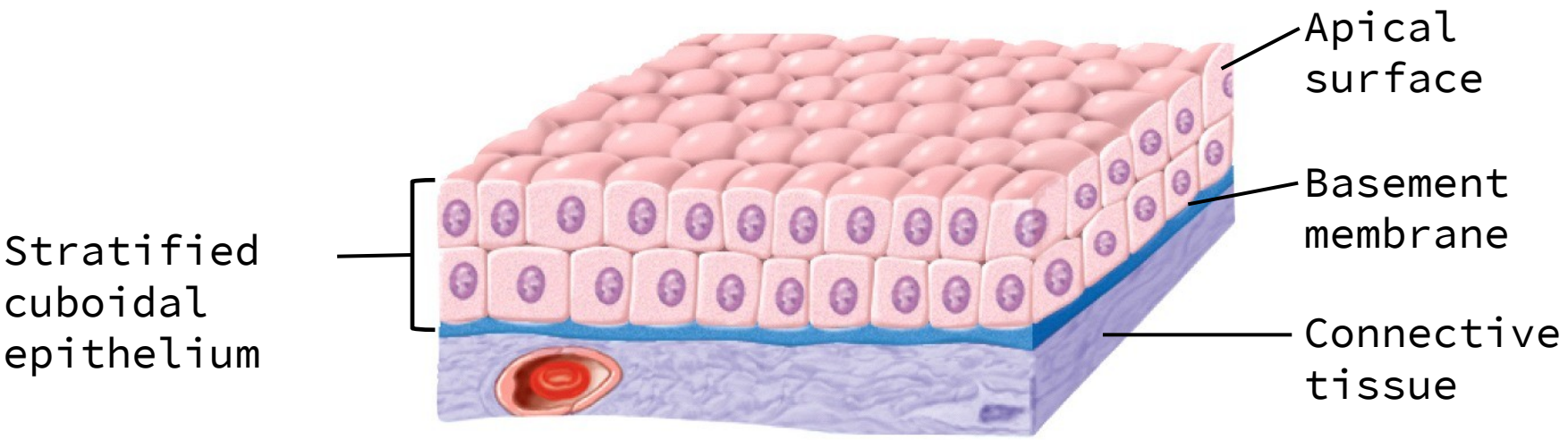

Stratified cuboidal epithelium

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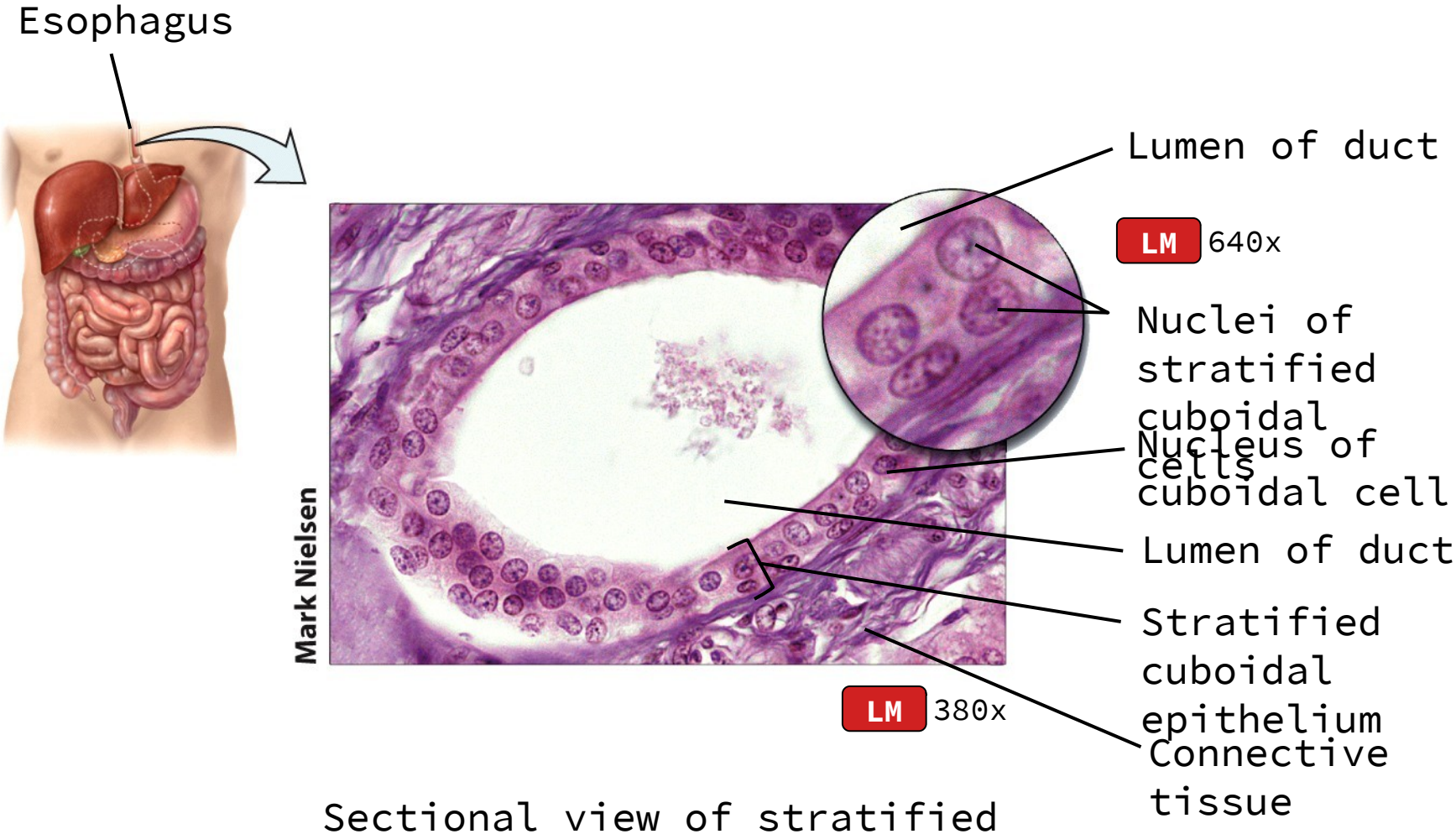

Sectional view of stratified epithelium of the duct of an esophageal gland

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Stratified Columnar Epithelium

TABLE 3.1

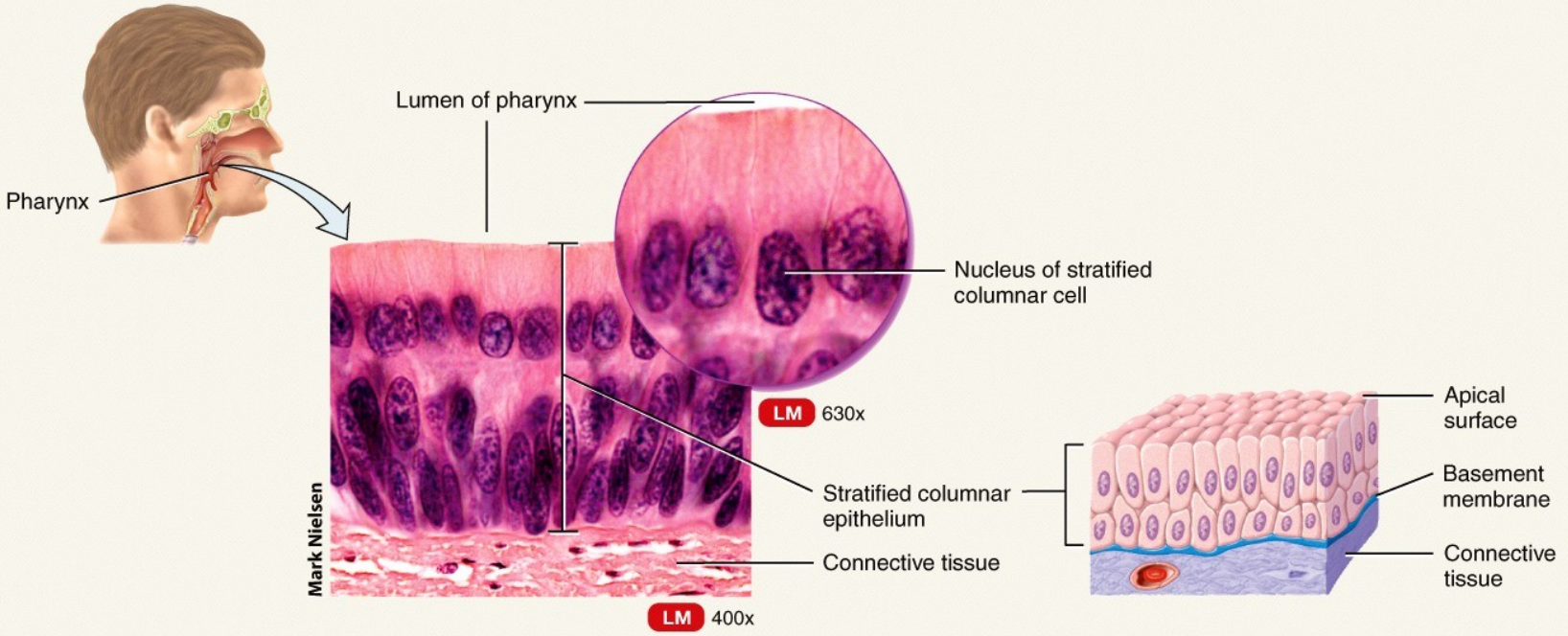
Epithelial Tissue: Covering and Lining Epithelium

H. STRATIFIED COLUMNAR EPITHELIUM

Description: Usually the basal layers consist of shortened, irregularly shaped cells; only the apical layer has cells that are columnar in shape. Like stratified cuboidal epithelium, stratified columnar epithelium also is uncommon.

Location: Lines part of urethra, large excretory ducts of some glands, such as esophageal glands, small areas in anal mucous membrane, and part of the conjunctiva of the eye.

Function: Protection and secretion.



Sectional view of stratified columnar epithelium of lining of pharynx

Stratified columnar epithelium

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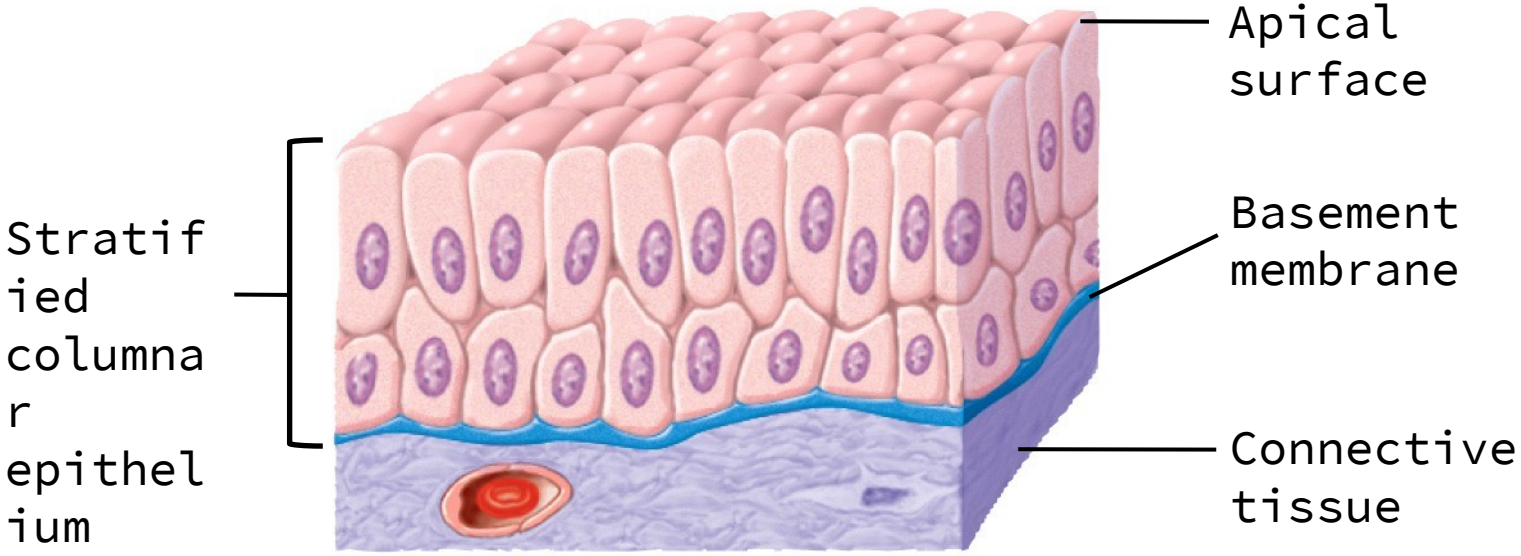

Stratified columnar epithelium

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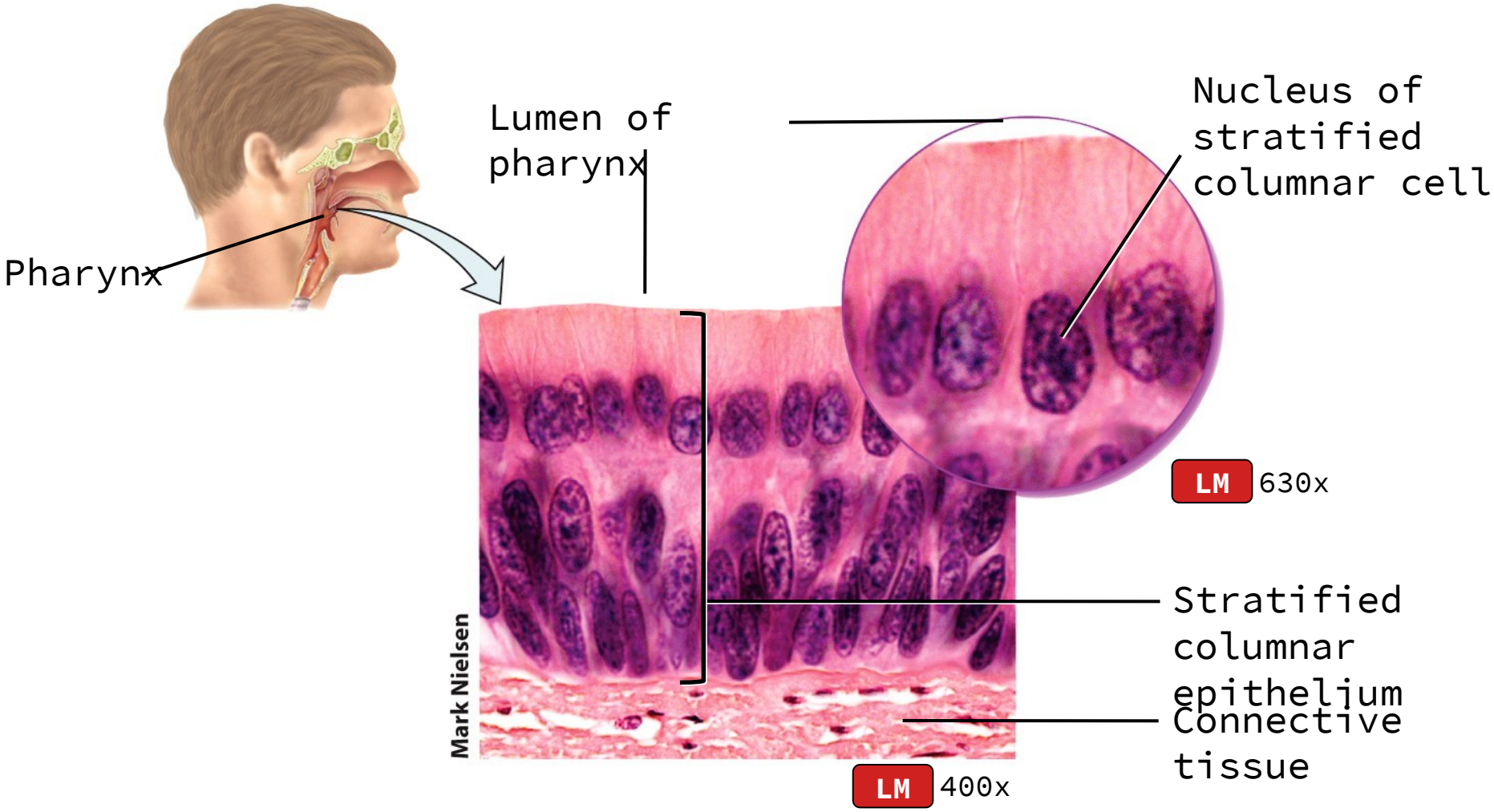

Sectional view of stratified columnar epithelium of lining arynx

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Transitional Epithelium

TABLE 3.1

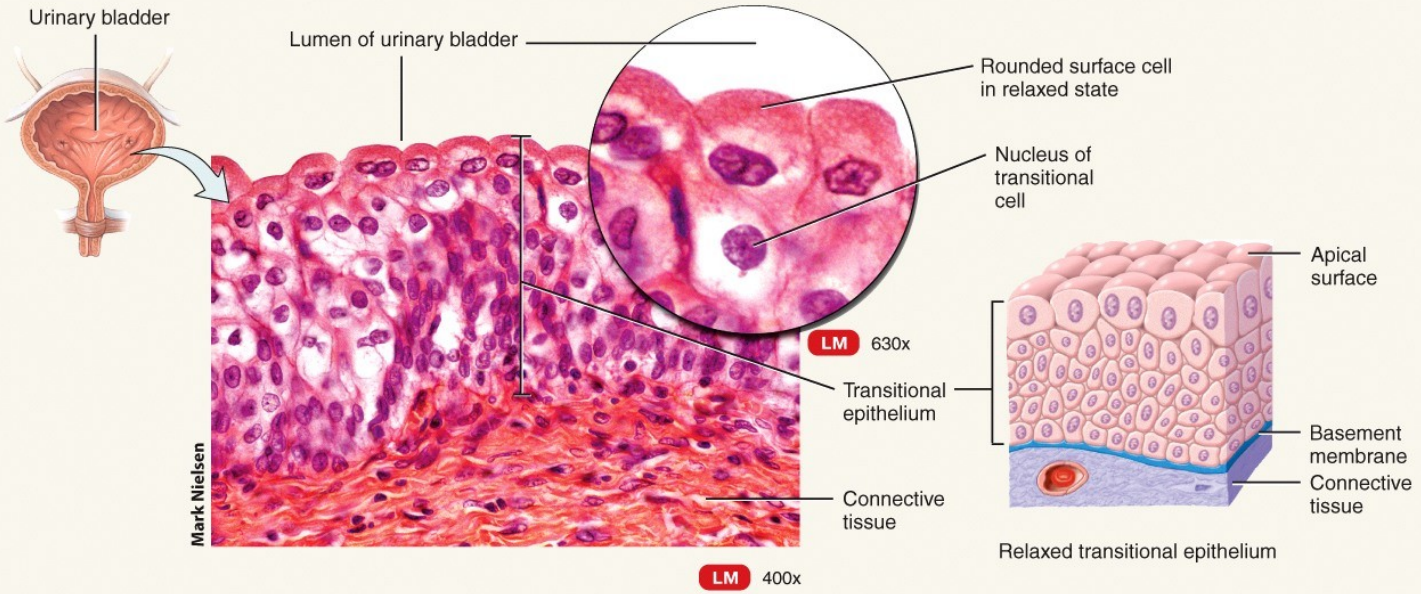
Epithelial Tissue: Covering and Lining Epithelium

I. TRANSITIONAL EPITHELIUM

Description: Appearance is variable (transitional). In its relaxed or unstretched state, transitional epithelium looks like stratified cuboidal epithelium, except that the cells in the apical layer tend to be large and rounded. As the tissue is stretched, its cells become flatter, giving the appearance of stratified squamous epithelium. Because of its multiple layers and elasticity, it is ideal for lining hollow structures (such as the urinary bladder) that are subject to expansion from within.

Location: Lines urinary bladder and portions of ureters and urethra.

Function: It allows the urinary organs to stretch to hold a variable amount of fluid without rupturing, while still serving as a protective lining.



Sectional view of transitional epithelium of urinary bladder in relaxed (empty) state

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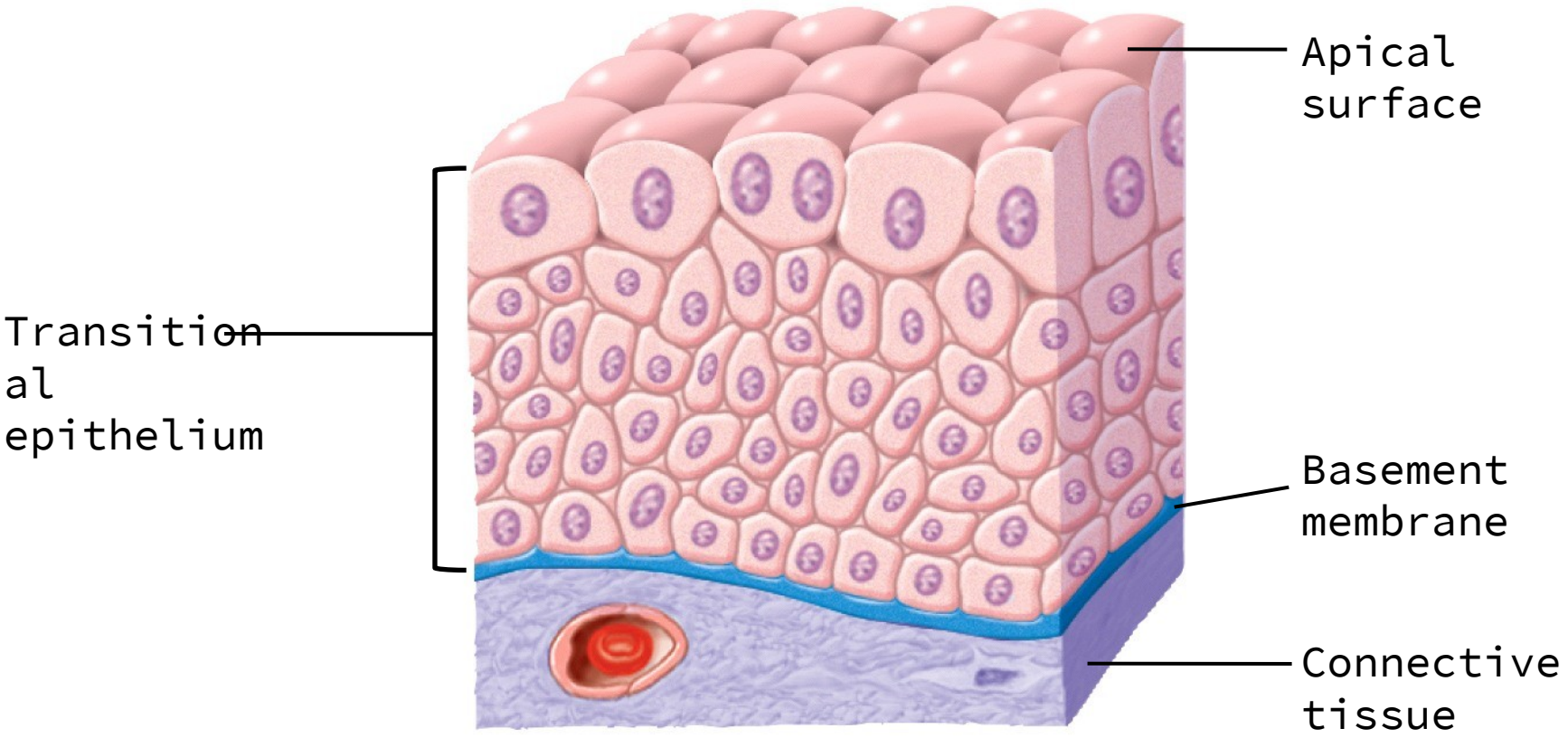

Relaxed transitional epithelium

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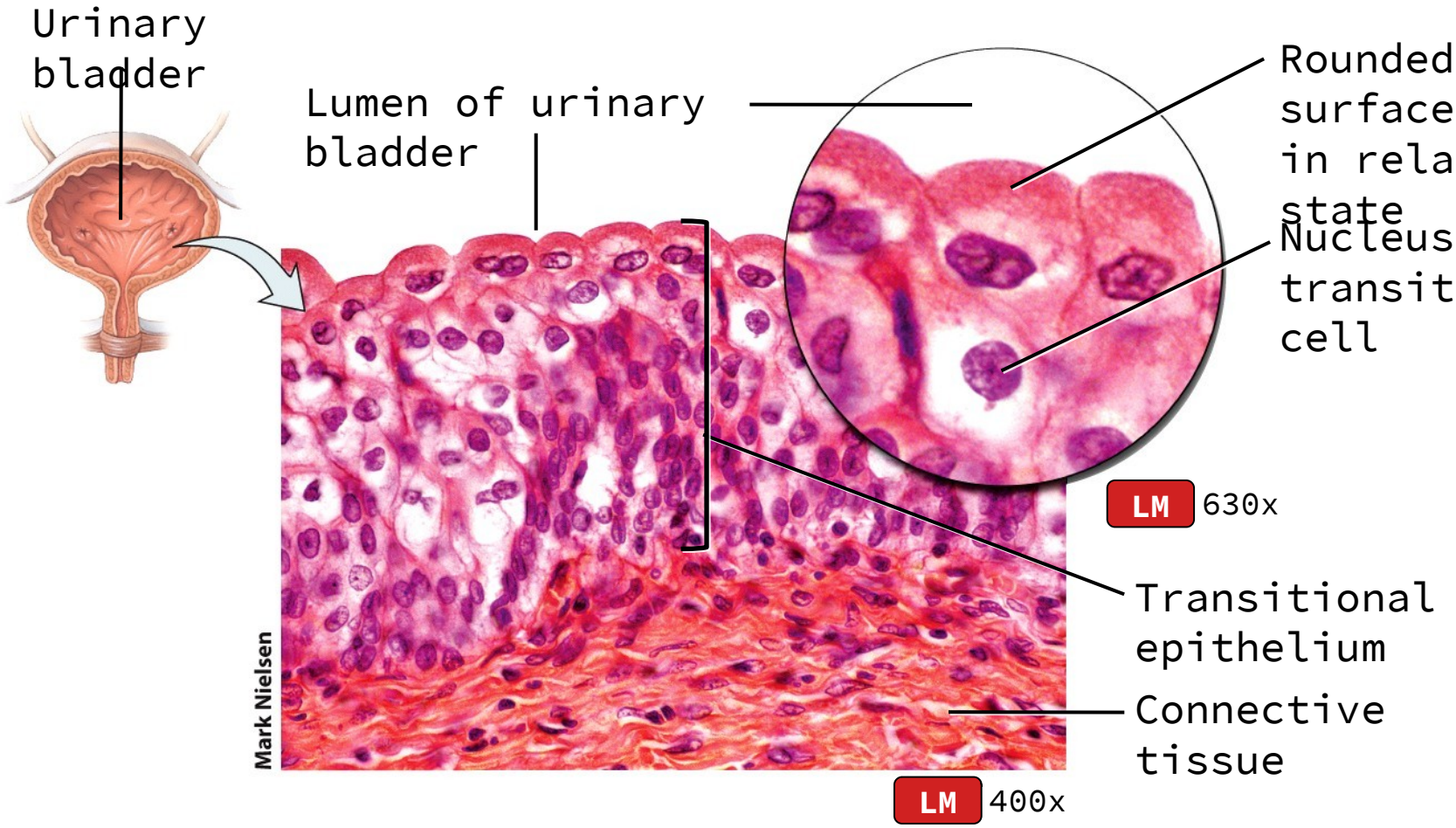

Sectional view of transitional epithelium of urinary bladder in :y) state

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Clinical Connection

Papanicolaou test (Pap test or Pap smear)

- Collection and microscopic examination of epithelial cells that have been scraped off the apical layer of a tissue**.**

- A method of cervical screening used to detect **early changes** in the cells: potentially pre-cancerous and cancerous processes in the cervix (opening of the uterus or womb) caused by sexually transmitted **human papillomaviruses (HPV).**

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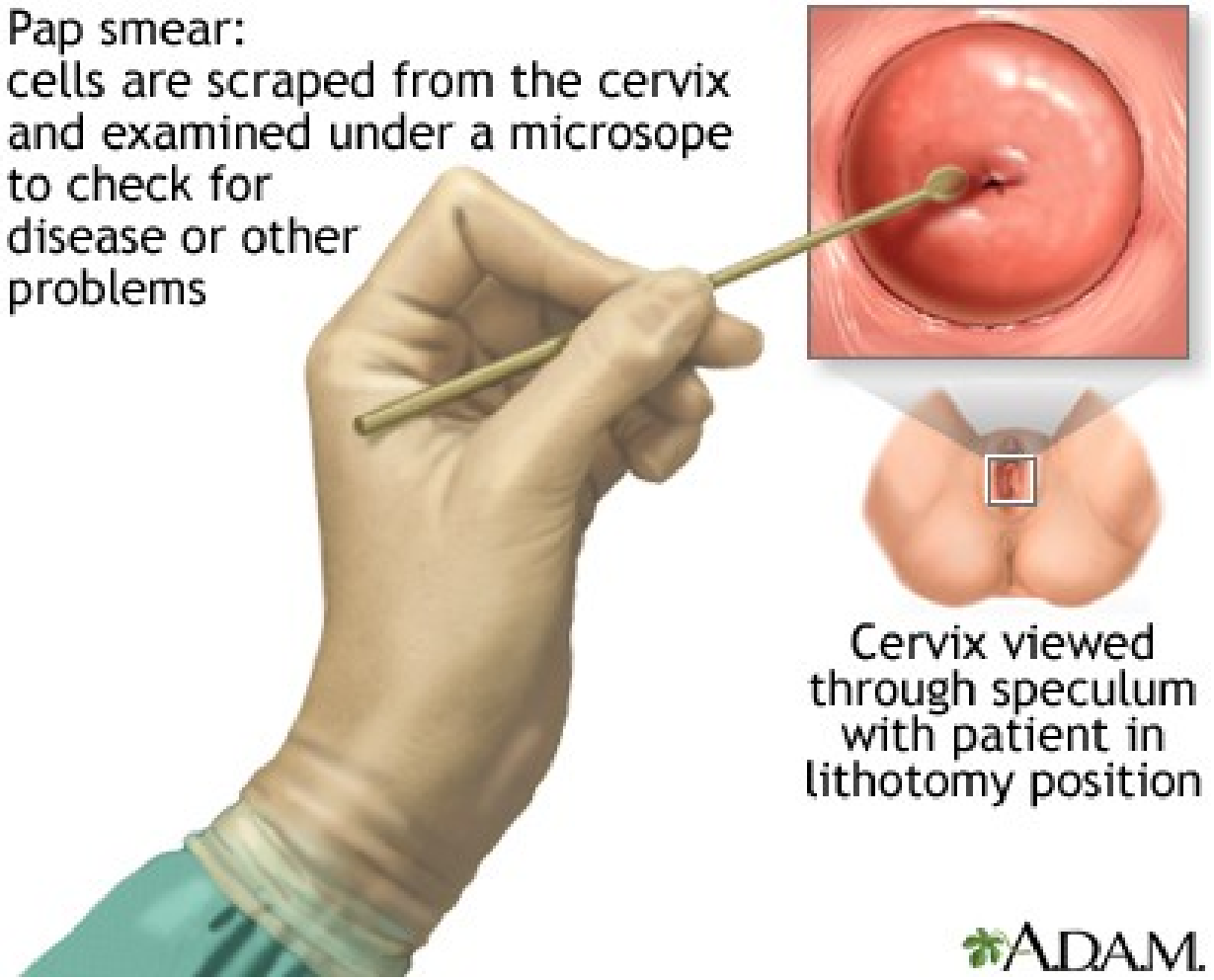
Clinical Connection



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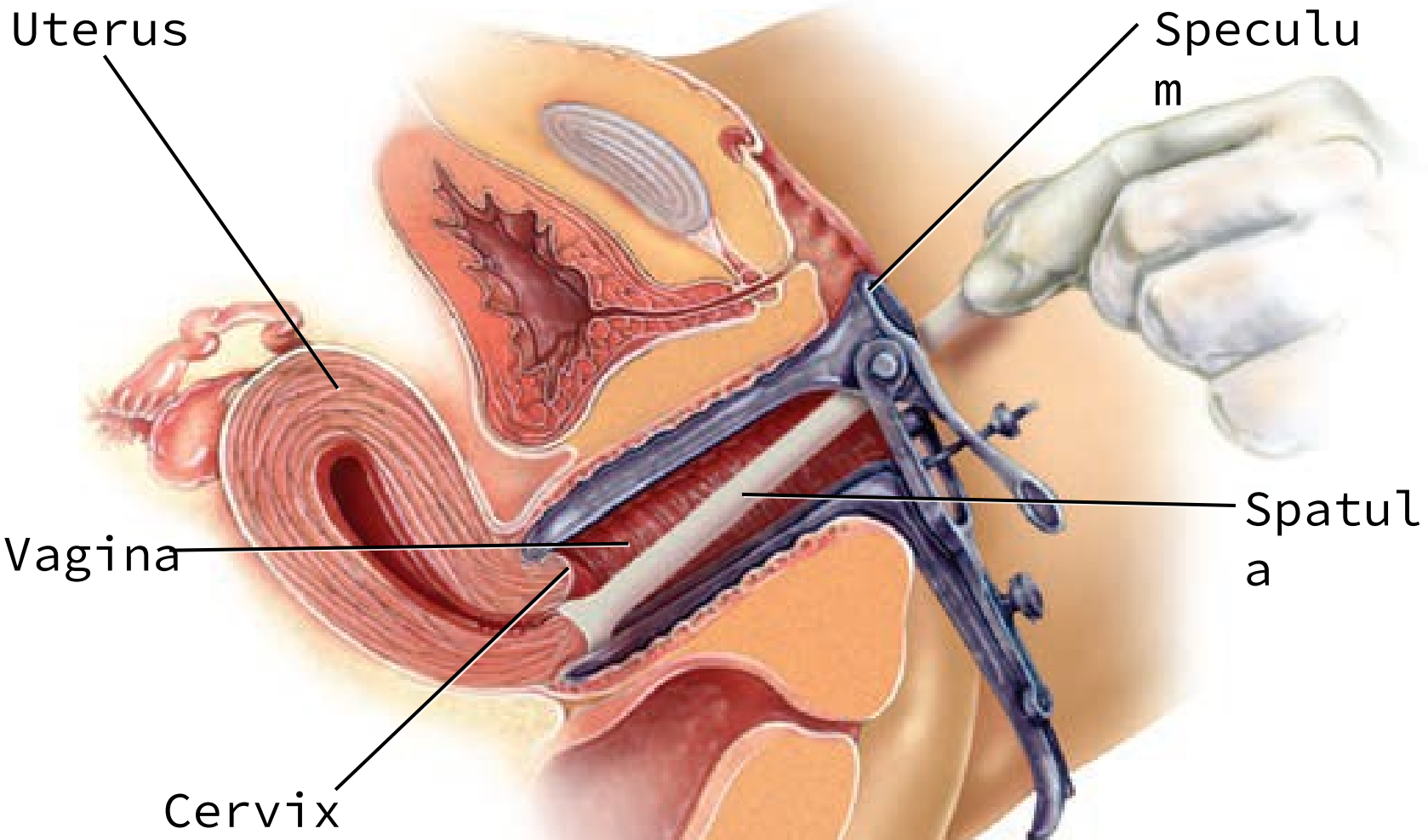

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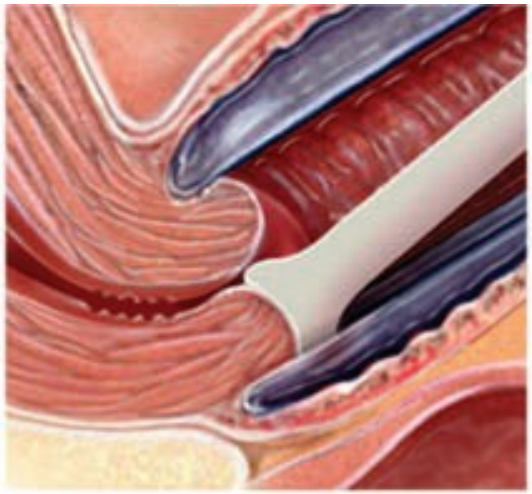
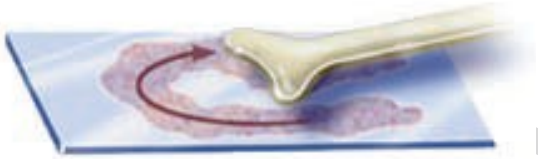
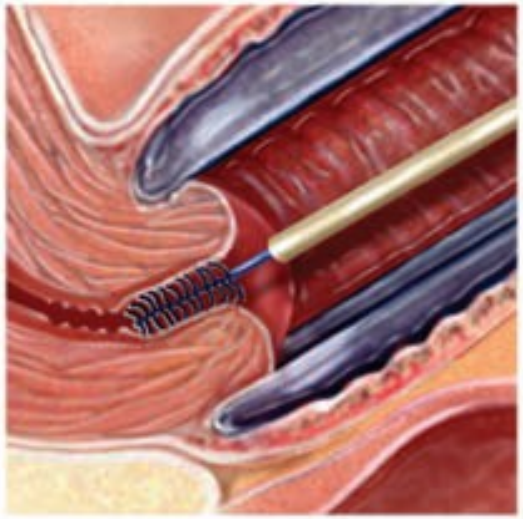
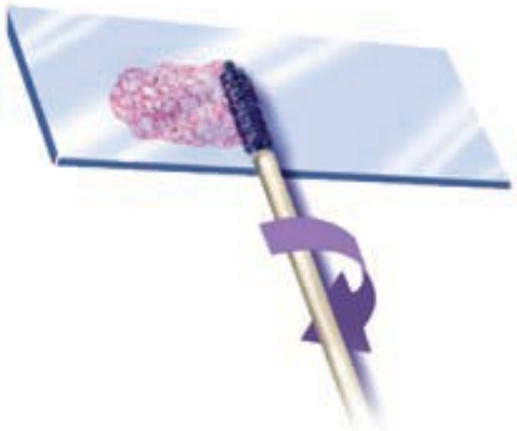




Sample from outside cervix





Sample from inside cervix

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Screening Guidelines – Cervical Cancer

Screening Initiation: 21 years of age for women who are or have been sexually active (intercourse, digital or oral sexual activity involving genital area with a partner of either gender). Delay in women until they are sexually active.

Screening Interval: if normal cytology, screen every 3 years

Screening Cessation: 70 years of age if there is adequate negative cytology screening history in previous 10 years (3 + negative cytology tests)

Pregnant women – continue schedule as above except perform pre/post natal instead
Partial/subtotal hysterectomy (retained cervix); Women who have sex with women; Women who have received the HPV vaccine should all continue as above schedule

Exceptions: Women with dysplasia, or are immunocompromised – annually
History of endometrial cancer – discontinue – false positives

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Glandular Epithelium

- Specialized epithelial cells organized to form **glands** that **secrete** substances into ducts, onto a surface, or into the blood
- Endocrine glands
- Exocrine glands

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Glandular Epithelium:

- **endocrine glands**
  - ductless (e.g., thyroid gland, adrenal glands)
  - secrete **hormones** which diffuse through the interstitial fluid into the blood.

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Endocrine Glands

TABLE 3.2

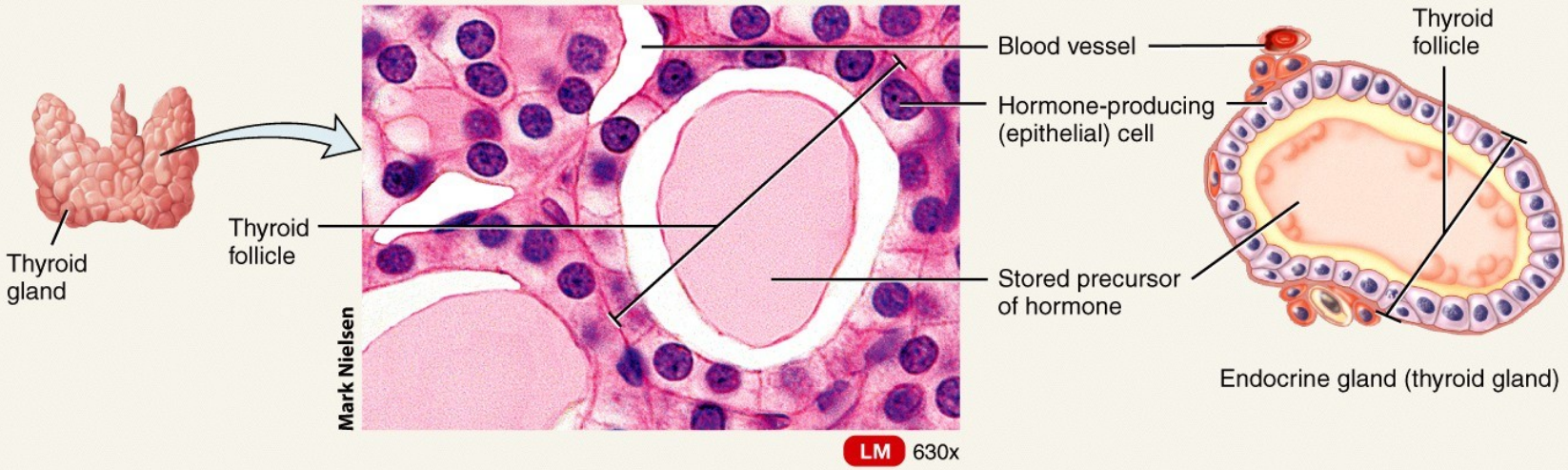
Epithelial Tissue: Glandular Epithelium

A. ENDOCRINE GLANDS

Description: The secretions, called *hormones*, made by endocrine glands enter the interstitial fluid and then diffuse directly into the bloodstream without flowing through a duct. Endocrine glands will be described in detail in Chapter 22.

Location: Examples include pituitary gland at base of brain, pineal gland in brain, thyroid and parathyroid glands near larynx (voice box), adrenal glands superior to kidneys, pancreas near stomach, ovaries in pelvic cavity, testes in scrotum, and thymus in thoracic cavity.

Function: Hormones regulate many metabolic and physiological activities to maintain homeostasis.



Sectional view of endocrine gland (thyroid gland)

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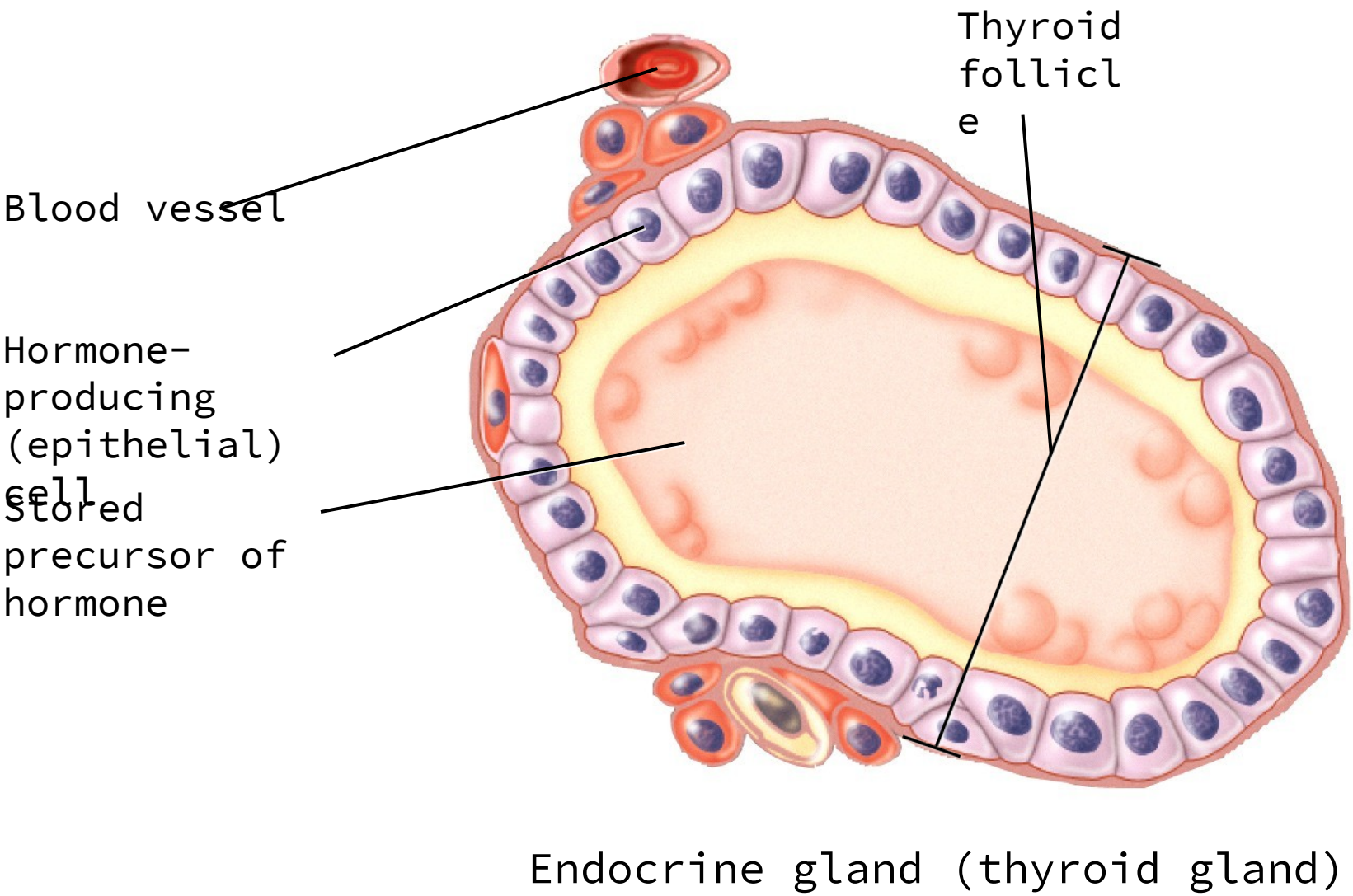

Endocrine gland (thyroid gland)

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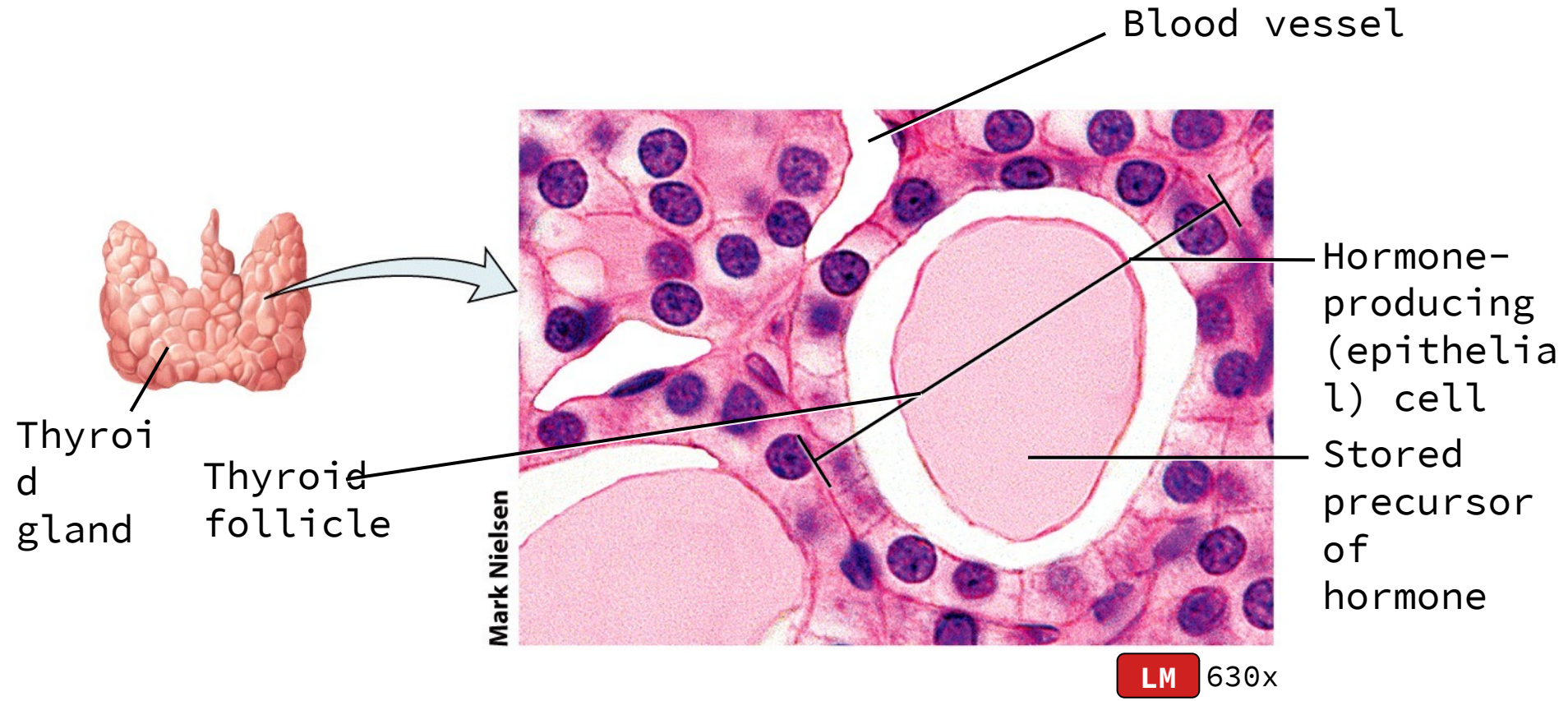

Sectional view of endocrine gland
id gland)

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Glandular Epithelium

- **exocrine glands** (e.g., sweat glands, salivary glands)
  - secrete substances (e.g., sweat, saliva) into **ducts**
  - structurally classified into
    - **unicellular**
    - **multicellular glands** (including **simple** or **compound** as well as **tubular**, **acinar** and **tubuloacinar** glands)
  - functionally classified into
    - **merocrine** or **eccrine** (e.g., salivary glands)
    - **apocrine** (e.g., mammary glands)
    - **holocrine** (e.g., sebaceous) glands

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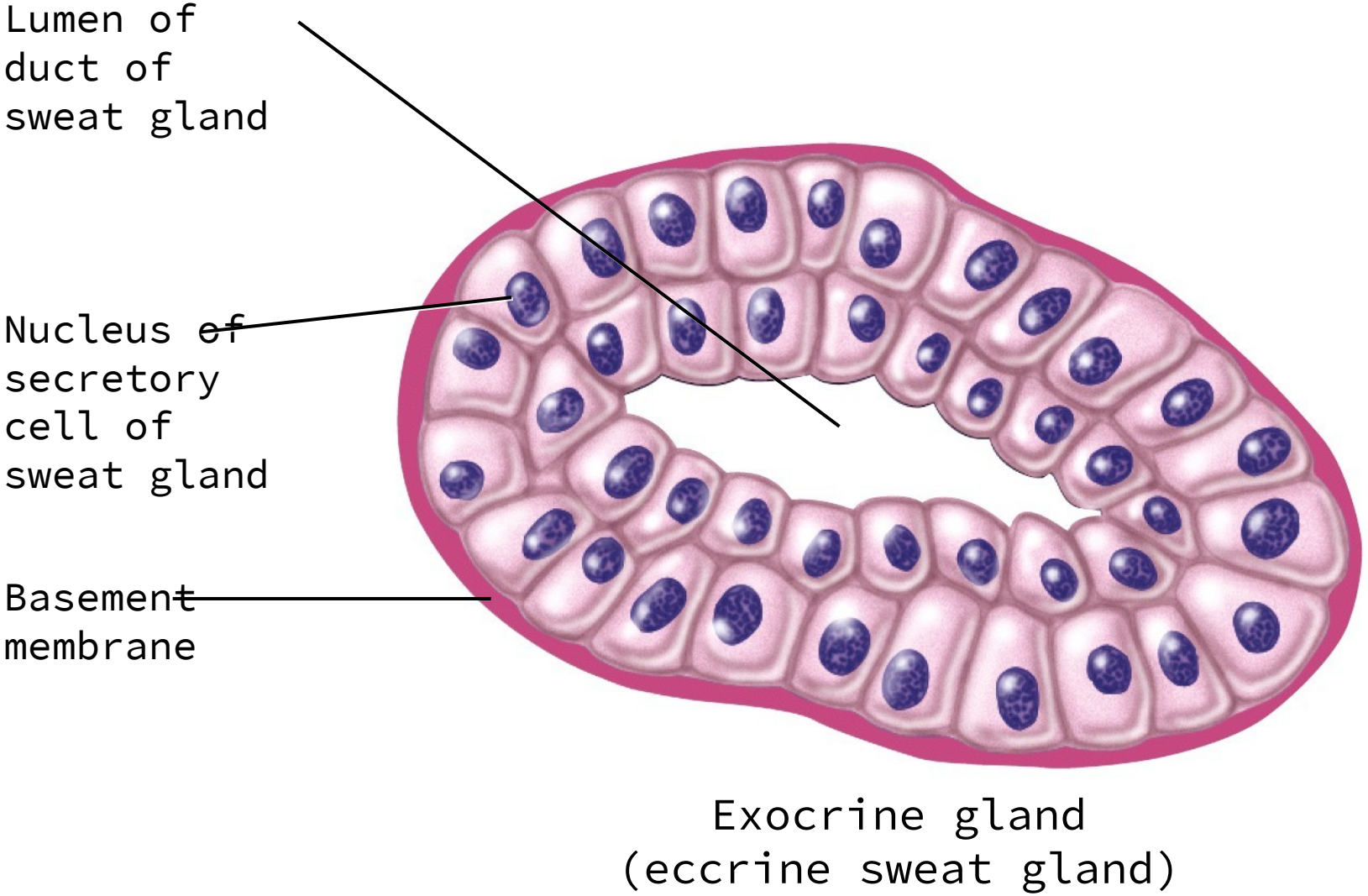

Exocrine gland
(eccrine sweat gland)

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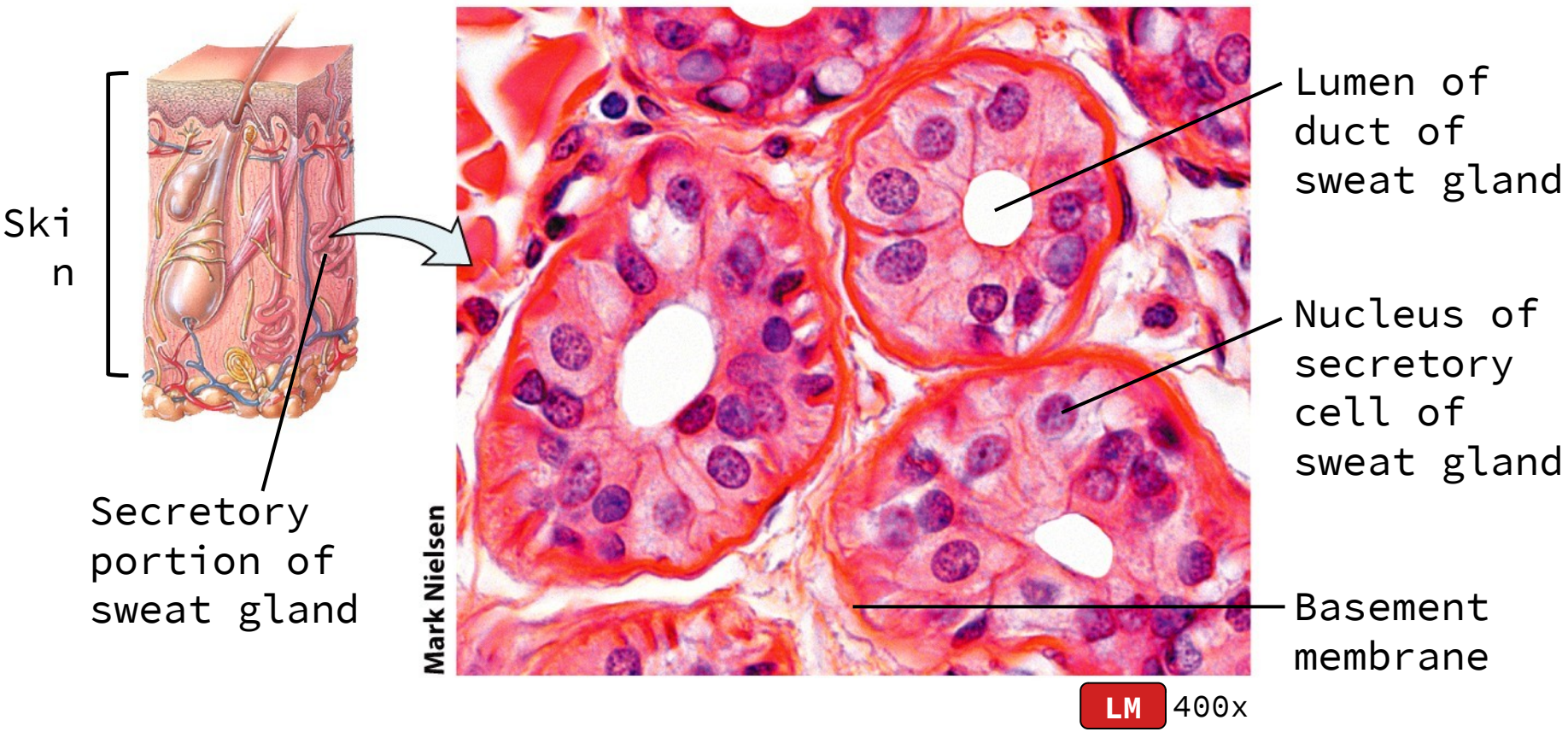

Sectional view of the secretory portion of an exocrine gland
ne sweat gland)

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Exocrine Glands: Structural Classification

Unicellular

- Single-celled glands
- Goblet cells are important unicellular exocrine glands that secrete mucus directly onto the apical surface of a lining epithelium.

Multicellular glands

- Composed of many cells that form a distinctive microscopic structure or macroscopic organ.
- Examples: sudoriferous, sebaceous (oil), and salivary glands.

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Exocrine Glands: Structural Classification

Multicellular glands

- Categorized according to two criteria:
  - whether their ducts are branched or unbranched
  - shape of the secretory portions of the gland
- **simple gland:** duct of the gland does not branch
- **compound gland:** duct branches
- **tubular glands:** have tubular secretory parts
- **acinar glands (***alveolar glands)***:** have rounded secretory portions
- **tubuloacinar glands:** have both tubular and more rounded secretory parts.

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Glands - Classification: Simple & Compound

Simple Exocrine Glands

- Simple tubular
- Simple branched tubular
- Simple coiled tubular
- Simple acinar
- Simple branched acinar

Compound Exocrine Glands

- Compound tubular
- Compound acinar
- Compound tubuloacinar

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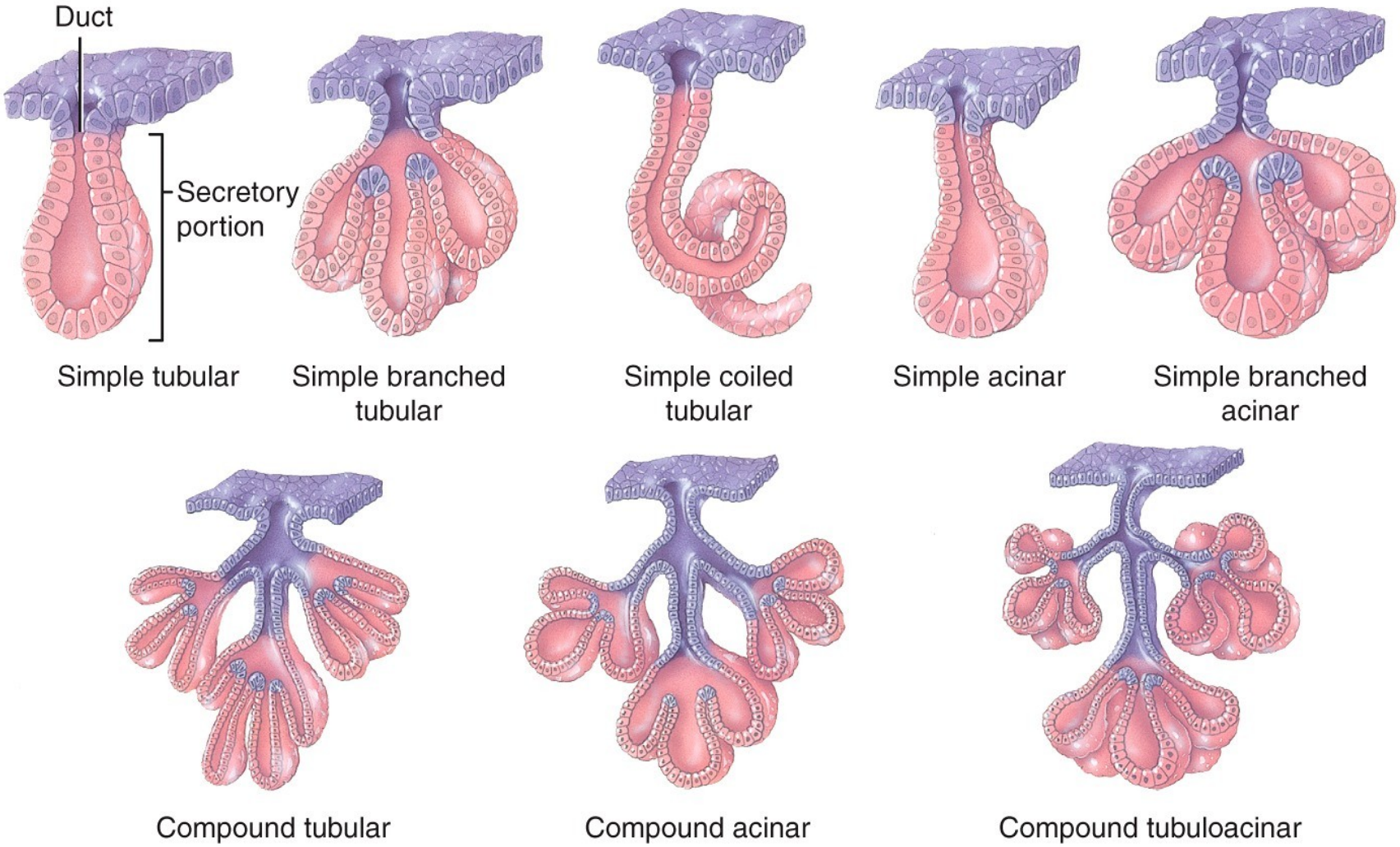
Multicellular Exocrine Glands



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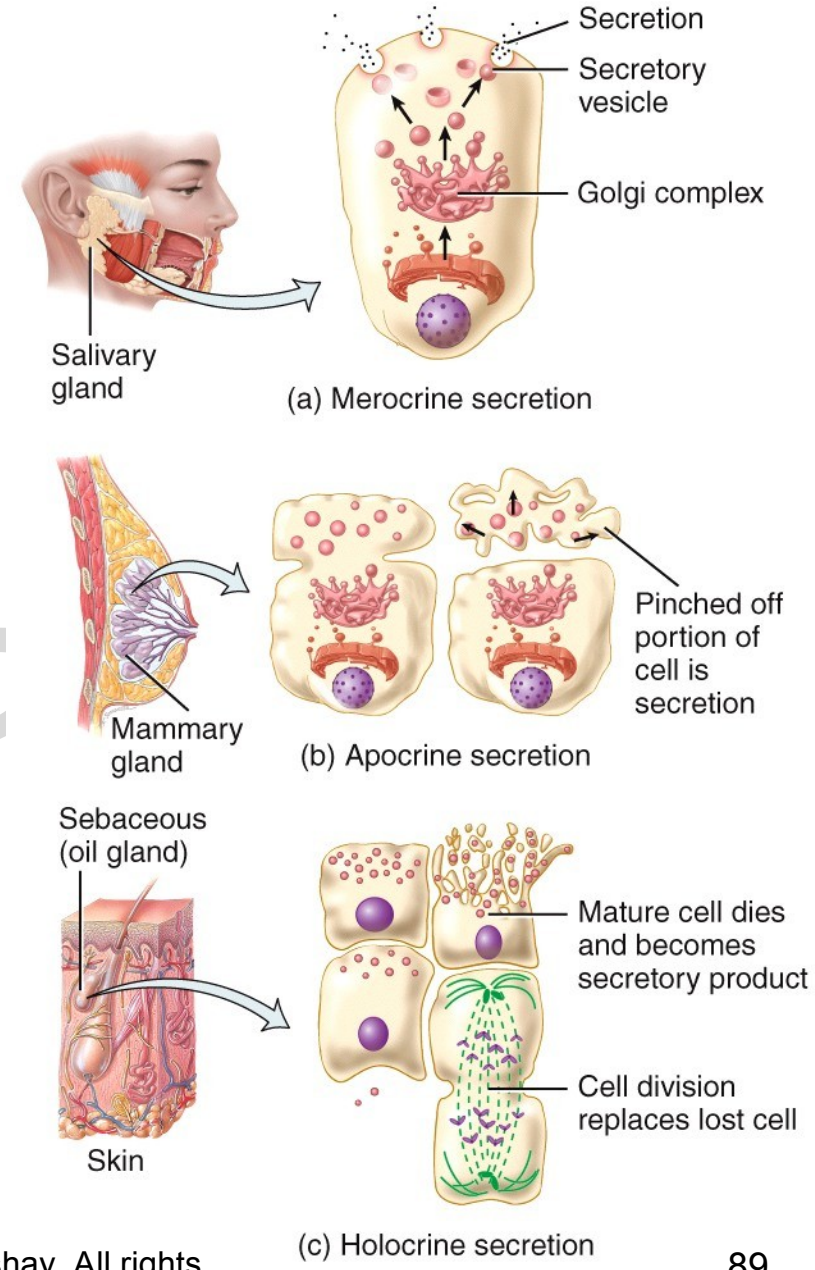
Functional Classification of Multicellular Exocrine Glands



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Exocrine Glands: Functional Classification

Based on **how their secretions are released**.

Each of these secretory processes begins with the *endoplasmic reticulum and Golgi complex* working together to form intracellular secretory vesicles that contain the secretory product.

- Merocrine (eccrine)
- Apocrine
- Holocrine

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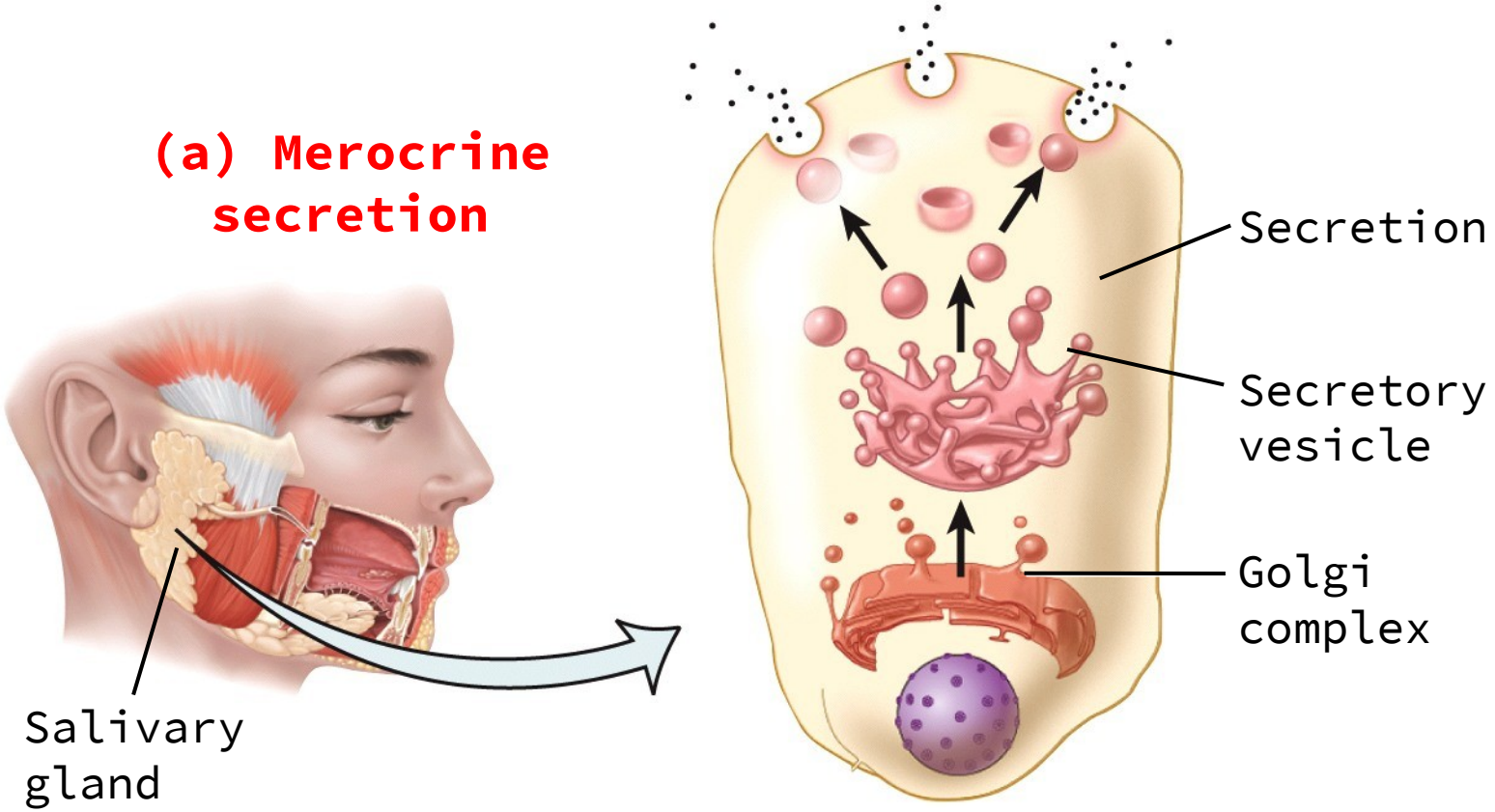

merocrine glands (**eccrine glands):**

•Secretions are synthesized on ribosomes attached to rough ER; processed, sorted, and packaged by the Golgi complex; and released from the cell in secretory vesicles via exocytosis.

•Most exocrine glands of the body are merocrine glands

•Examples include the salivary glands and pancreas.

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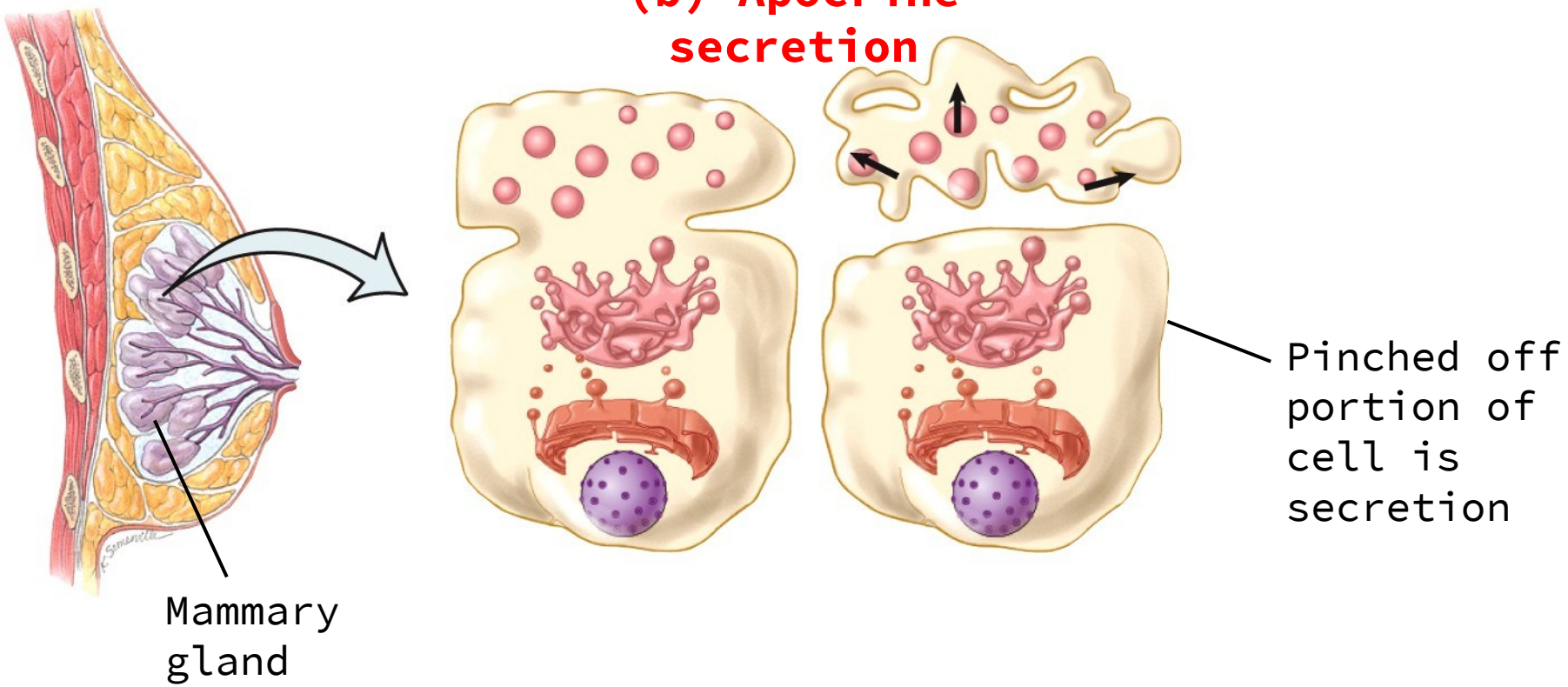

Apocrine glands

•accumulate their secretory product at the apical surface of the secreting cell. Then, that portion of the cell pinches off from the rest of the cell to release the secretion. The remaining part of the cell repairs itself and repeats the process. Electron microscopy has recently confirmed that this is the mechanism of secretion of milk fats in the mammary glands. Recent evidence reveals that the sweat glands of the skin, named apocrine sweat glands after this mode of secretion, actually undergo merocrine secretion.

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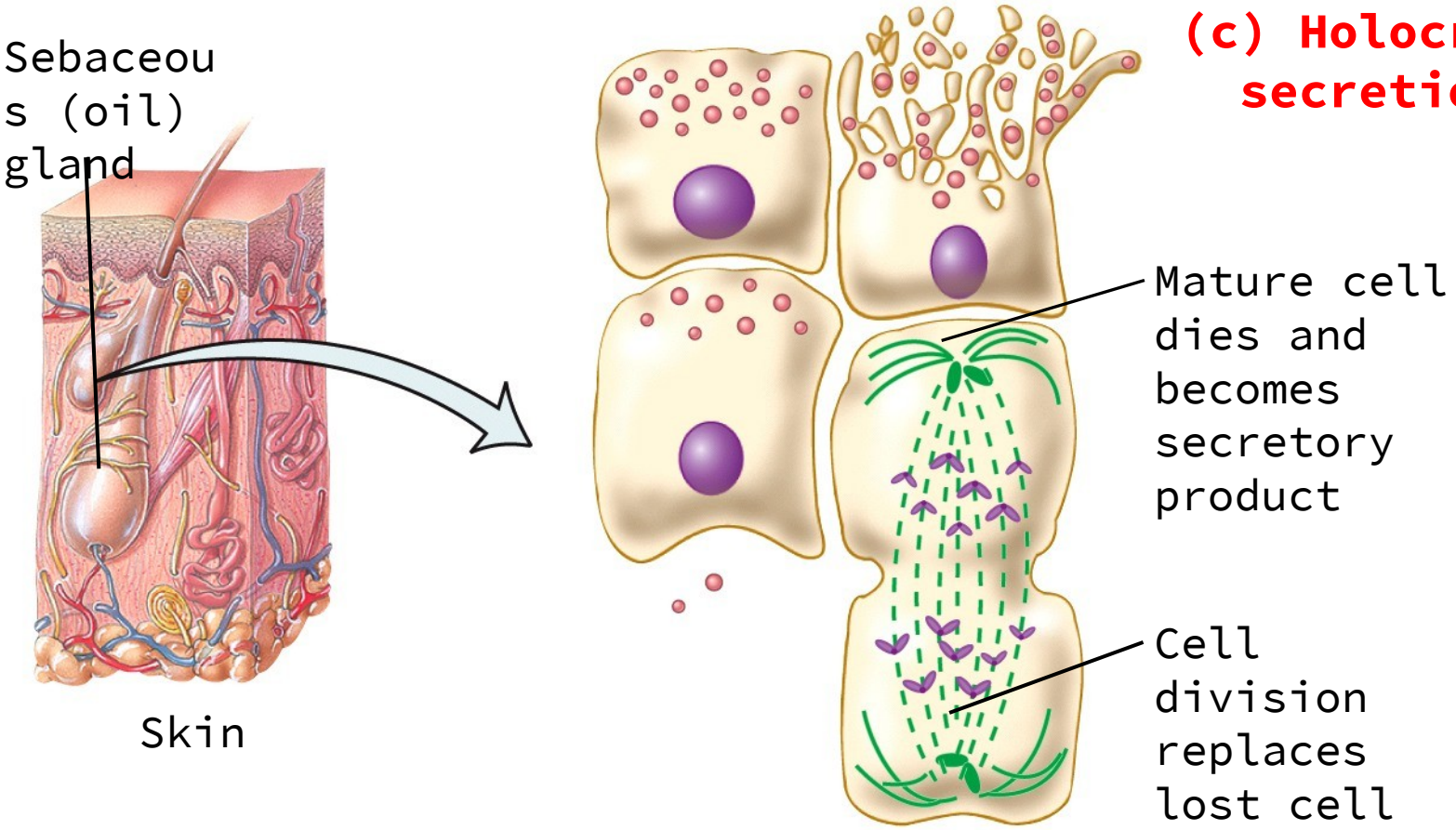

Holocrine glands

•accumulate a secretory product in their cytosol. As the secretory cell matures, it ruptures and becomes the secretory product

•Because the cell ruptures in this mode of secretion, the secretion consists of a considerable amount of lipids from the plasma membrane and intracellular membranes. The sloughed-off cell is replaced by a new cell. One example of a holocrine gland is a sebaceous gland of the skin.

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Connective Tissue

- Connective tissue is one of the most abundant and widely distributed tissues in the body
  - Fibroblasts
  - Macrophages
  - Plasma cells
  - Mast cells
  - Adipocytes
  - White blood cells

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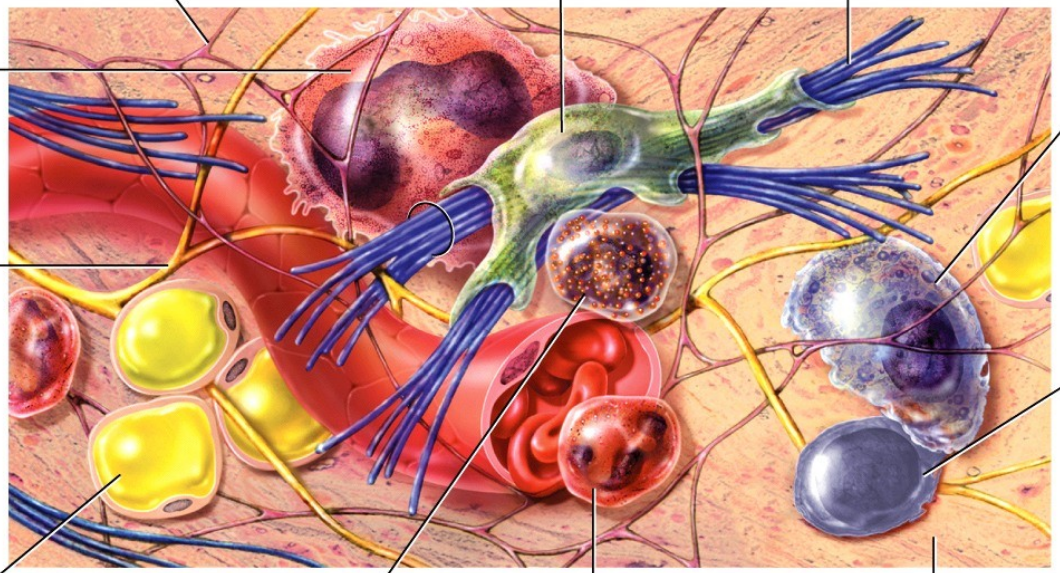
Representative Cells and Fibers in Connective Tissue



RETICULAR FIBERS
are made of collagen and glycoproteins. They provide support in blood vessel walls and form branching networks around various cells (fat, smooth muscle, nerve).

FIBROBLASTS
are large flat cells that move through connective tissue and secrete fibers and ground substance.

COLLAGEN FIBERS
are strong, flexible bundles of the protein collagen, the most abundant protein in your body.

MACROPHAGES
develop from monocytes and destroy bacteria and cell debris by phagocytosis.

ELASTIC FIBERS
are stretchable but strong fibers made of proteins, elastin, and fibrillin. They are found in skin, blood vessels, and lung tissue.

MAST CELLS
are abundant along blood vessels. They produce histamine, which dilates small blood vessels during inflammation and kills bacteria.

PLASMA CELLS
develop from B lymphocytes. They secrete antibodies that attack and neutralize foreign substances.

ADIPOCYTES
or fat cells store fats. They are found below the skin and around organs (heart, kidney).

EOSINOPHILS
are white blood cells that migrate to sites of parasitic infection and allergic responses.

NEUTROPHILS
are white blood cells that migrate to sites of infection that destroy microbes by phagocytosis.

GROUND SUBSTANCE
is the material between cells and fibers. It is made of water and organic molecules (hyaluronic acid, chondroitin sulfate, glucosamine). It supports cells and fibers, binds them together, and provides a medium for exchanging substances between blood and cells.

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Connective Tissue: Functions

- binds together, supports and strengthens other tissues
- protects and insulates internal organs
- compartmentalizes certain structures (e.g., skeletal muscles)
- blood is a connective tissue that transports substances
- adipose (fat) tissue stores energy reserves
- is the main source of immune responses

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Connective Tissue: General Features

- composed of
  - *connective tissue cells*
    - Secrete protein fibers into extracellular matrix
  - *extracellular matrix*
    - ground substance and fibers
    - has variable qualities (e.g., fluid, gelatinous, calcified)
    - not usually located on free surfaces
- has a rich blood supply (except in cartilage and tendons)
- has a nerve supply (except in cartilage)

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Characteristics of Connective Tissue Cells

- derived from **mesenchyme**
- **immature** cells have names that end with ***-blast*** (e.g., osteoblast, chondroblast, fibroblast); they **retain** the capacity for cell division and secrete the matrix
- **mature** cells have names that end with ***-cyte*** (e.g., osteocyte); they usually have a **reduced** capacity for cell division and matrix secretion; their major role is maintenance of the matrix
- some notable examples of cells include *fibroblasts, macrophages, plasma cells, mast cells, adipocytes, and leukocytes*

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Connective Tissue Cells - Types

Fibroblasts

- large, flat cells with branching processes
- present in all the general connective tissues, and usually the most numerous.
- migrate through the connective tissue, secreting the fibers and certain components of the ground substance of the extracellular matrix.

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Connective Tissue Cells - Types

Macrophages

- develop from *monocytes,* a type of white blood cell
- have an irregular shape with short branching projections
- capable of engulfing bacteria and cellular debris by phagocytosis
- *Fixed macrophages* reside in a particular tissue; eg. alveolar macrophages in lungs; splenic macrophages in spleen.
- *Wandering macrophages* have the ability to move throughout the tissue and gather at sites of infection or inflammation to carry out phagocytosis.

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Connective Tissue Cells - Types

Plasma cells

- small cells that develop from a type of white blood cell called a ***B*** *lymphocyte*
- secrete antibodies (proteins that attack or neutralize foreign substances in the body)
- found in many places in the body, mostly in connective tissues, especially in the gastrointestinal and respiratory tracts. They are also abundant in the salivary glands, lymph nodes, spleen, and red bone marrow.

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Connective Tissue Cells - Types

Mast cells

- abundant alongside the blood vessels that supply connective tissue
- produce histamine, a chemical that dilates small blood vessels as part of the inflammatory response, the body's reaction to injury or infection
- recently discovered that mast cells can bind to, ingest, and kill bacteria

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Connective Tissue Cells - Types

Adipocytes fat cells or *adipose* cells

- store triglycerides (fats)
- found deep to the skin and around organs such as the heart and kidneys.

White blood cells

- not found in significant numbers in normal connective tissue but in response to certain conditions, they migrate from blood into connective tissues
- *neutrophils* gather at sites of infection
- *eosinophils* migrate to sites of parasitic invasions and allergic responses

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Anatomy Overview:

- Connective Tissues

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Connective Tissue – Extracellular Matrix

Consists of:

- **ground substance** that may be fluid, semifluid, gelatinous, or calcified and is composed of numerous polysaccharides (i.e., glycosaminoglycans) and proteins (i.e., proteoglycans)

- protein **fibers** including:
  - **collagen fibers** which provide strength and flexibility to the tissue
  - **elastic fibers** which provide strength and elasticity
  - **reticular fibers** which provide support and strength

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Ground Substance

- may be fluid, semifluid, gelatinous, or calcified
- supports cells, binds them together, stores water, and provides a medium for exchange of substances between the blood and cells
- plays an active role in how tissues develop, migrate, proliferate, and change shape, and in how they carry out their metabolic functions
- contains water and an assortment of large organic molecules, many of which are complex combinations of polysaccharides *(hyaluronic acid, chondroitin sulfate, dermatan sulfate, and keratin sulfate = GAGs)* and proteins

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Ground Substance

Glycosaminoglycans (GAGs)

- polysaccharides include *hyaluronic acid, chondroitin sulfate, dermatan sulfate, and keratin sulfate*
- associated with proteins called **proteoglycans** (except for hyaluronic acid)
- The proteoglycans form a core protein and the GAGs project from the protein like the bristles of a brush.
- One of the most important properties of GAGs is that they trap water, making the ground substance more jellylike.

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Ground Substance - GAGs

Hyaluronic acid

- viscous, slippery substance that binds cells together, lubricates joints, and helps maintain the shape of the eyeballs.
- *White blood cells, **sperm cells**, and some bacteria produce **hyaluronidase**, an enzyme that breaks apart hyaluronic acid, thus causing the ground substance of connective tissue to become **more liquid***. The ability to produce hyaluronidase helps white blood cells move more easily through connective tissues to reach sites of infection and aids penetration of an oocyte by a sperm cell during fertilization. It also accounts for the rapid spread of bacteria through connective tissues.

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Ground Substance - GAGs

Chondroitin sulfate

- provides support and adhesiveness in cartilage, bone, skin, and blood vessels

Dermatan sulfate

- found in skin, tendons, blood vessels, and heart valves

Keratan sulfate

- found in bone, cartilage, and the cornea of the eye

Adhesion proteins

- responsible for linking components of the ground substance to one another and to the surfaces of cells.
- Fibronectin is the main adhesive protein

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Clinical Connections - Gags

Chondroitin sulfate and **glucosamine** have been used as nutritional supplements either alone or in combination.

- promote and maintain the structure and function of joint cartilage
- provide pain relief from osteoarthritis
- reduce joint inflammation

Although these supplements have benefited some individuals with moderate to *severe* osteoarthritis, the benefit is minimal in lesser cases.

More research is needed to determine how they act and why they help some people and not others.

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Protein Fibers in Extracellular Matrix

<u>Collagen Fibers</u> ***(colla = glue)***

- consist of the protein *collagen (*most abundant protein in your body 25%)
- very strong, resist pulling forces (tension), but are not stiff, which allows tissue flexibility.
- properties of different types of collagen fibers vary from tissue to tissue (eg. cartilage collagen fibers are surrounded by more water molecules than those in bone which gives cartilage a more cushioning effect)
- can occur in parallel bundles which adds great tensile strength to the tissue
- found in most types of connective tissues, especially bone, cartilage, tendons (which attach muscle to bone), and ligaments (which attach bone to bone)

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Protein Fibers in Extracellular Matrix

Elastic fibers

- smaller in diameter than collagen fibers, branch and join together to form a fibrous network
- unique molecular structure - consist of molecules of protein *elastin* surrounded by a glycoprotein *fibrillin,*
- strong, can be stretched up to 150 percent of their relaxed length without breaking
- *Elasticity:* the ability to return to their original shape after being stretched
- elastic fibers are plentiful in skin, blood vessel walls, and lung tissue

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Protein Fibers in Extracellular Matrix

Reticular fibers

- produced by fibroblasts
- consisting of *collagen* arranged in fine bundles with a coating of glycoprotein much thinner than collagen fibers, form branching networks
- provide support and strength
  - provide support in blood vessel walls and form a network around the cells in some tissues (areolar connective tissue, adipose tissue, nerve fibers, smooth muscle tissue)
  - like collagen fibers plentiful in reticular connective tissue - forms the **stroma** or supporting framework of many soft organs (spleen, lymph nodes)
- helps form the basement membrane

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Clinical Connection - Marfan syndrome

- inherited disorder caused by a defective fibrillin gene
- abnormal development of elastic fibers - tissues rich in elastic fibers are malformed/weakened
- structures affected most seriously
  - periosteum (covering layer of bones)
  - ligament that suspends the lens of the eye
  - walls of the large arteries

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Classification of Connective Tissue

Embryonic connective tissue

- Mesenchyme gives rise to almost all other types of connective tissues
- Mucous connective tissue is found primarily in the umbilical cord of the fetus

Mature connective tissue

- Loose
- Dense
- Cartilage
- Bone
- Liquid

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Anatomy Overview:

- Connective Tissues

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Mesenchyme

TABLE 3.3

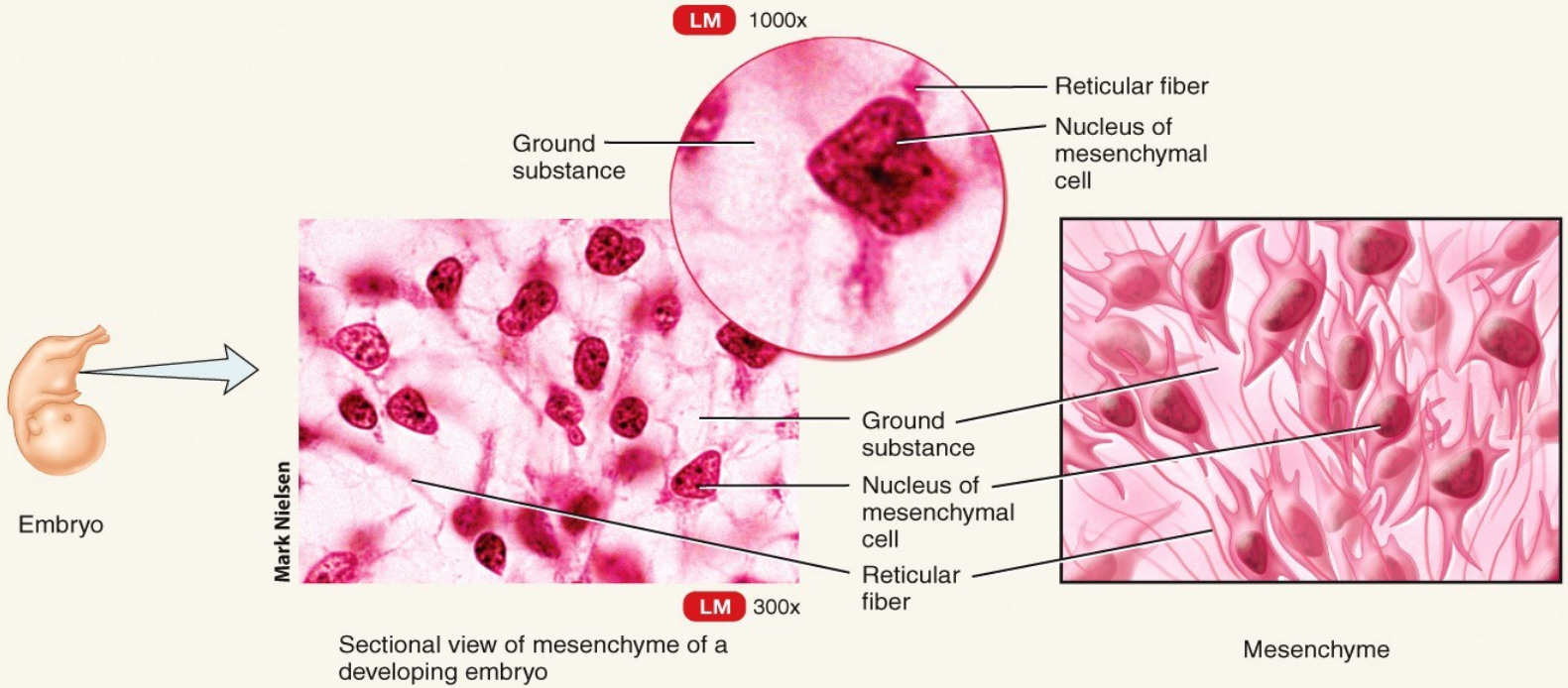
Embryonic Connective Tissue

A. MESENCHYME

Description: Consists of irregularly shaped mesenchymal cells embedded in a semifluid ground substance that contains delicate reticular fibers.

Location: Found almost exclusively in the embryo, under skin and along developing bones of embryo; some mesenchymal cells are found in adult connective tissue, especially along blood vessels.

Function: Forms almost all other types of connective tissue.



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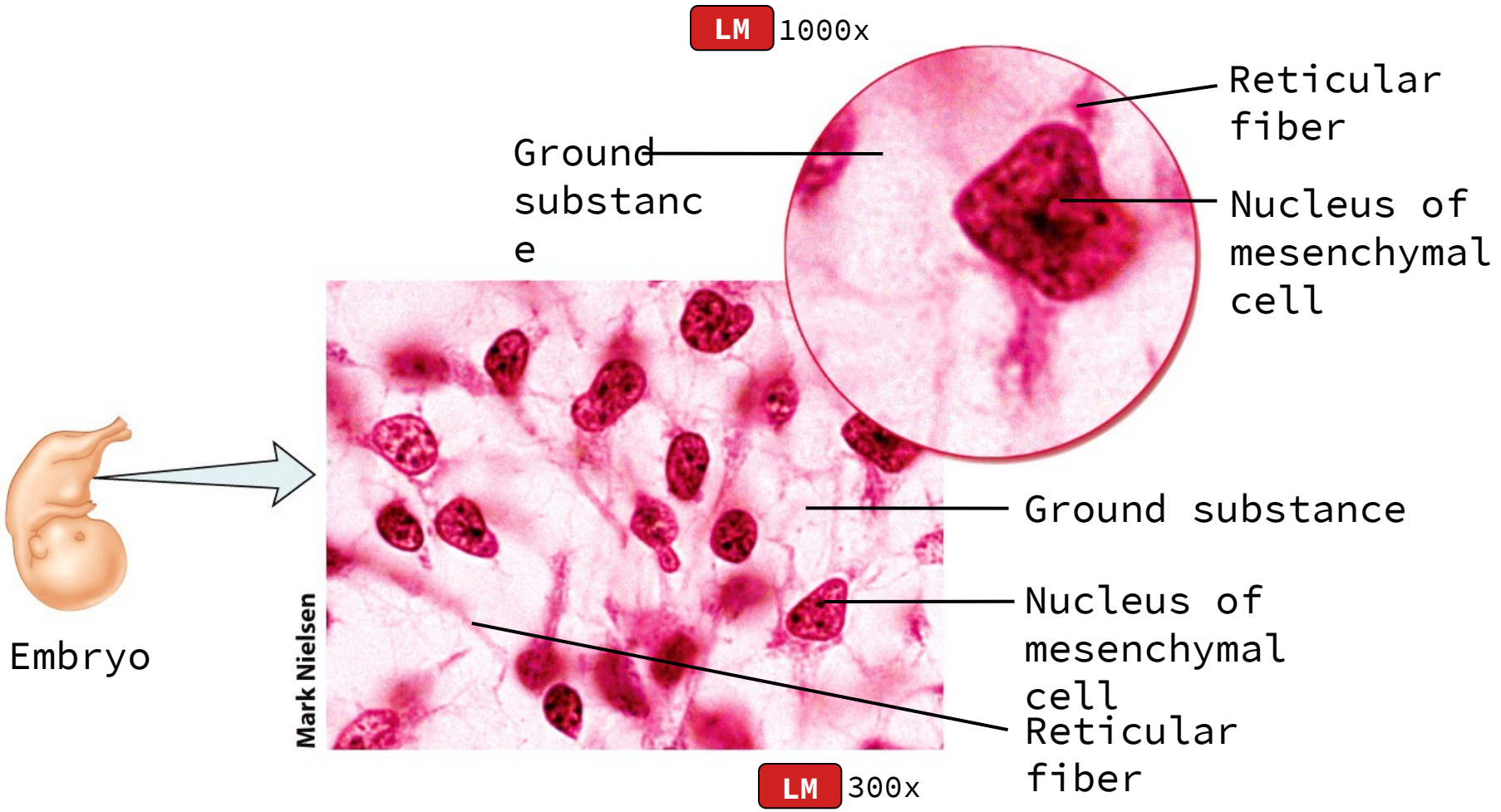

Sectional view of mesenchyme of a ng embryo

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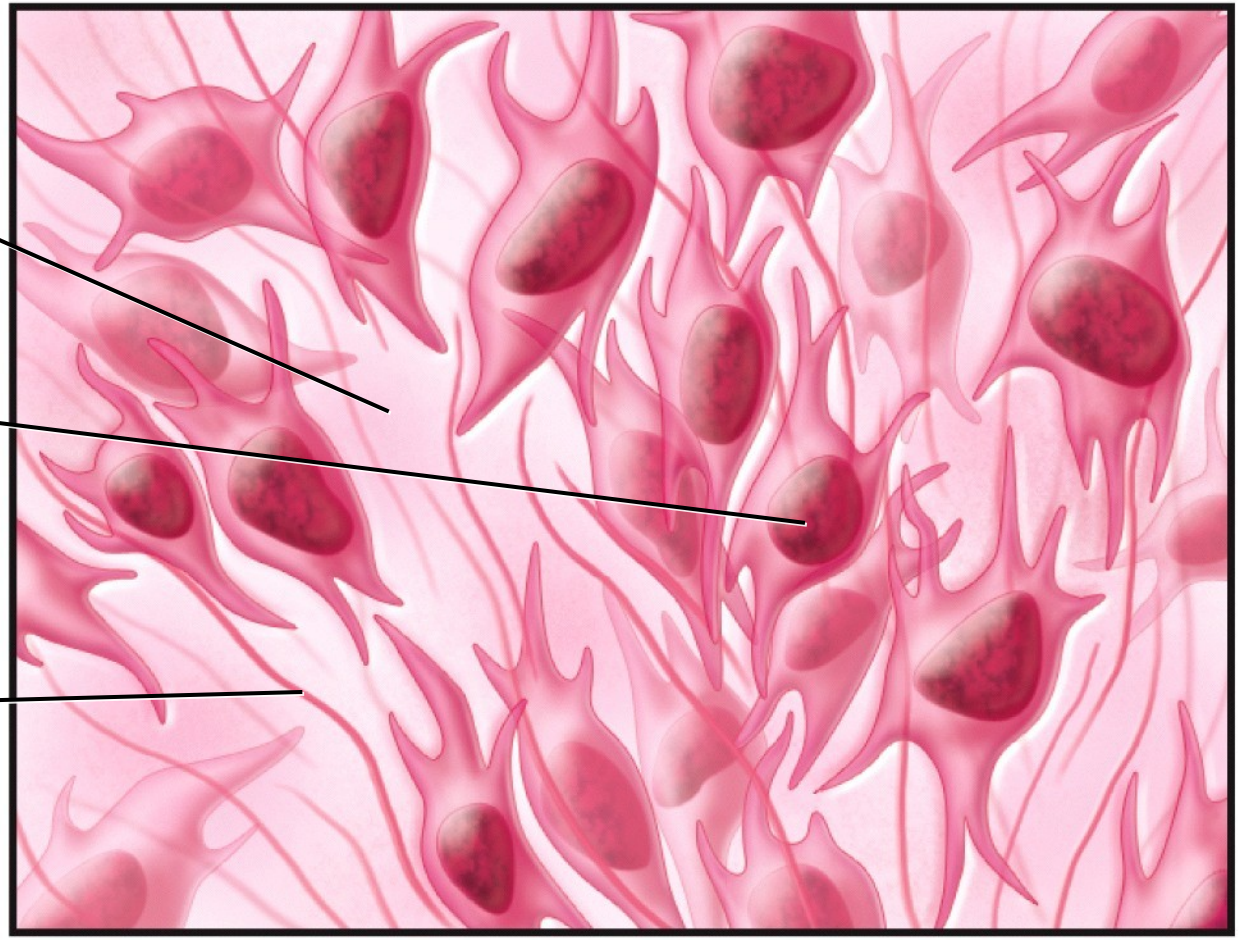

Mesenchyme

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Mucous Connective Tissue

TABLE 3.3

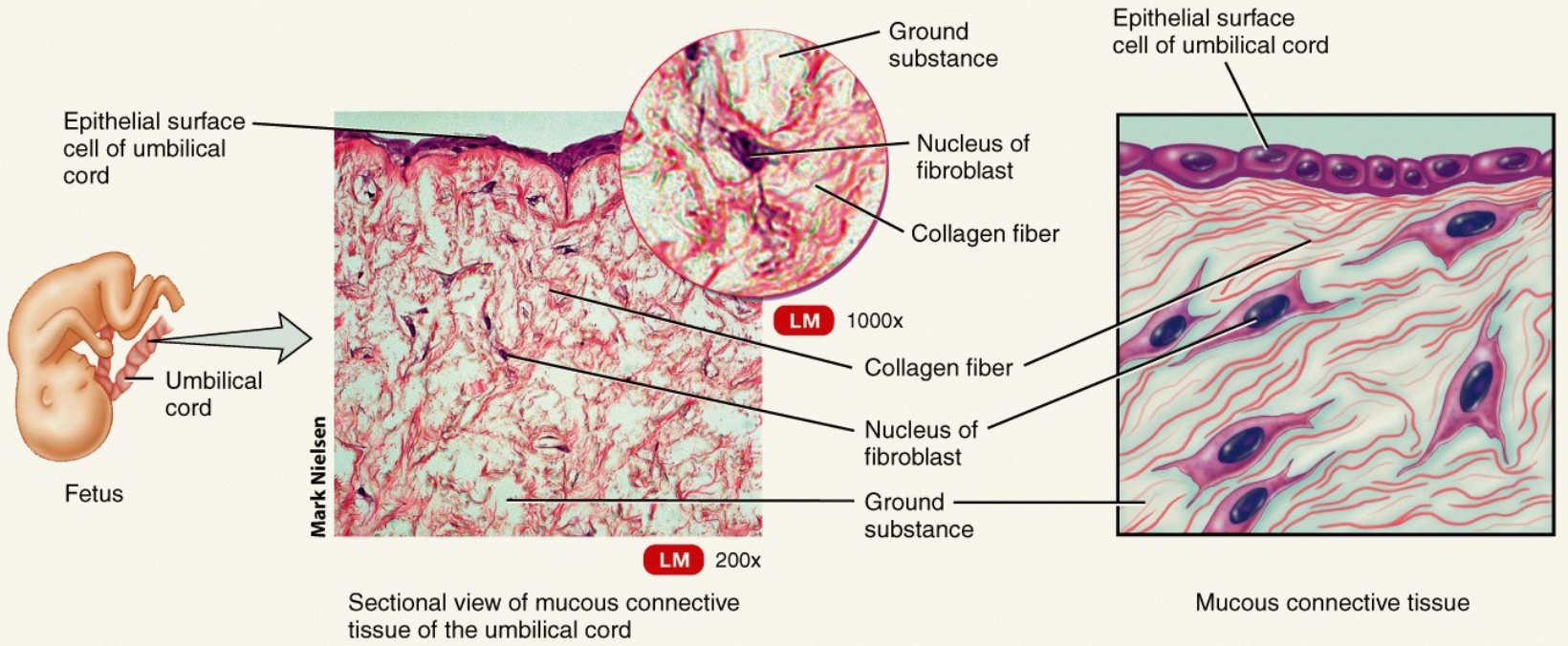
Embryonic Connective Tissue

B. MUCOUS CONNECTIVE TISSUE

Description: Consists of widely scattered fibroblasts embedded in a viscous, jellylike ground substance that contains fine collagen fibers.

Location: Umbilical cord of fetus.

Function: Support.



Sectional view of mucous connective tissue of the umbilical cord

Mucous connective tissue

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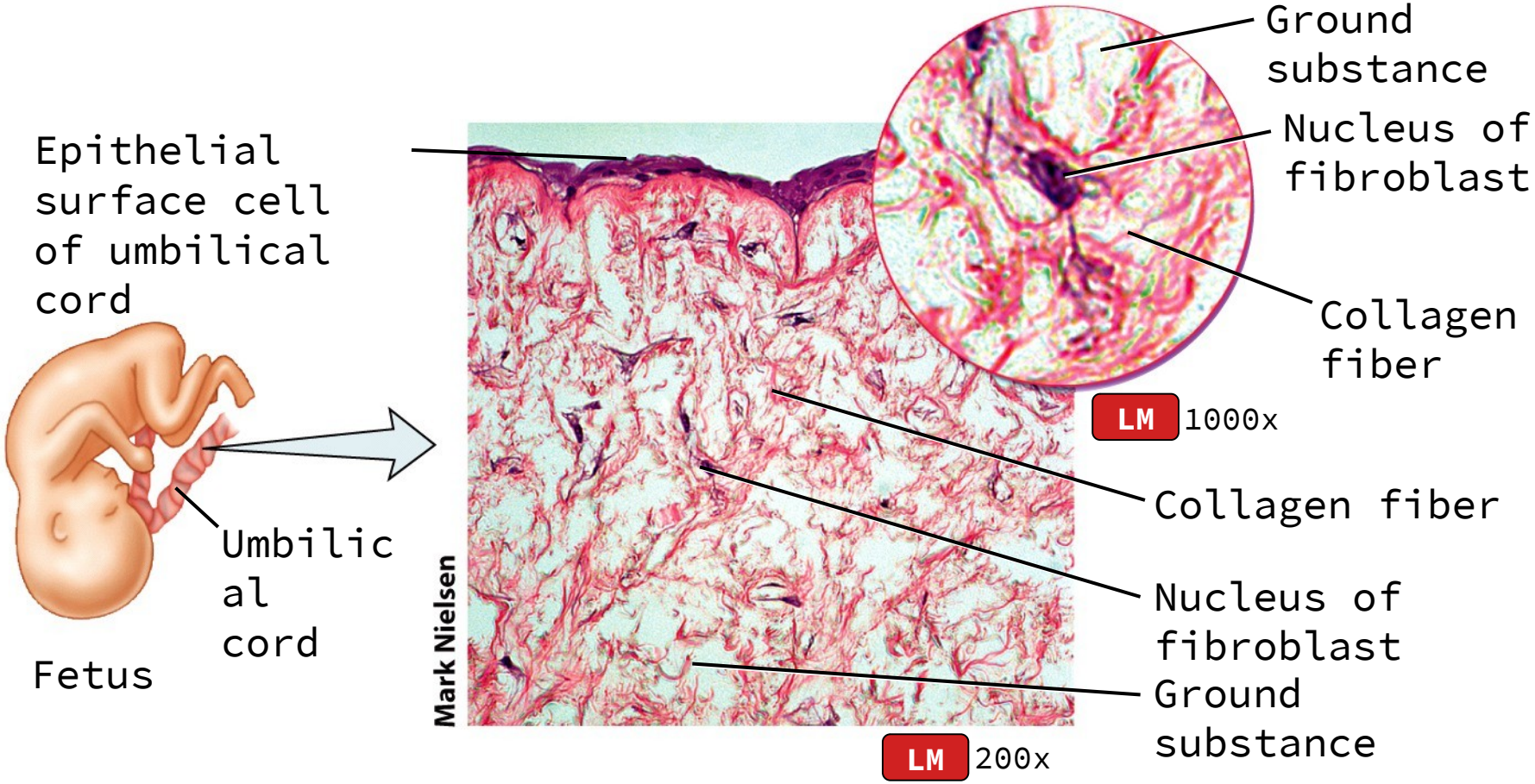

Sectional view of mucous connective tissue of the ical cord

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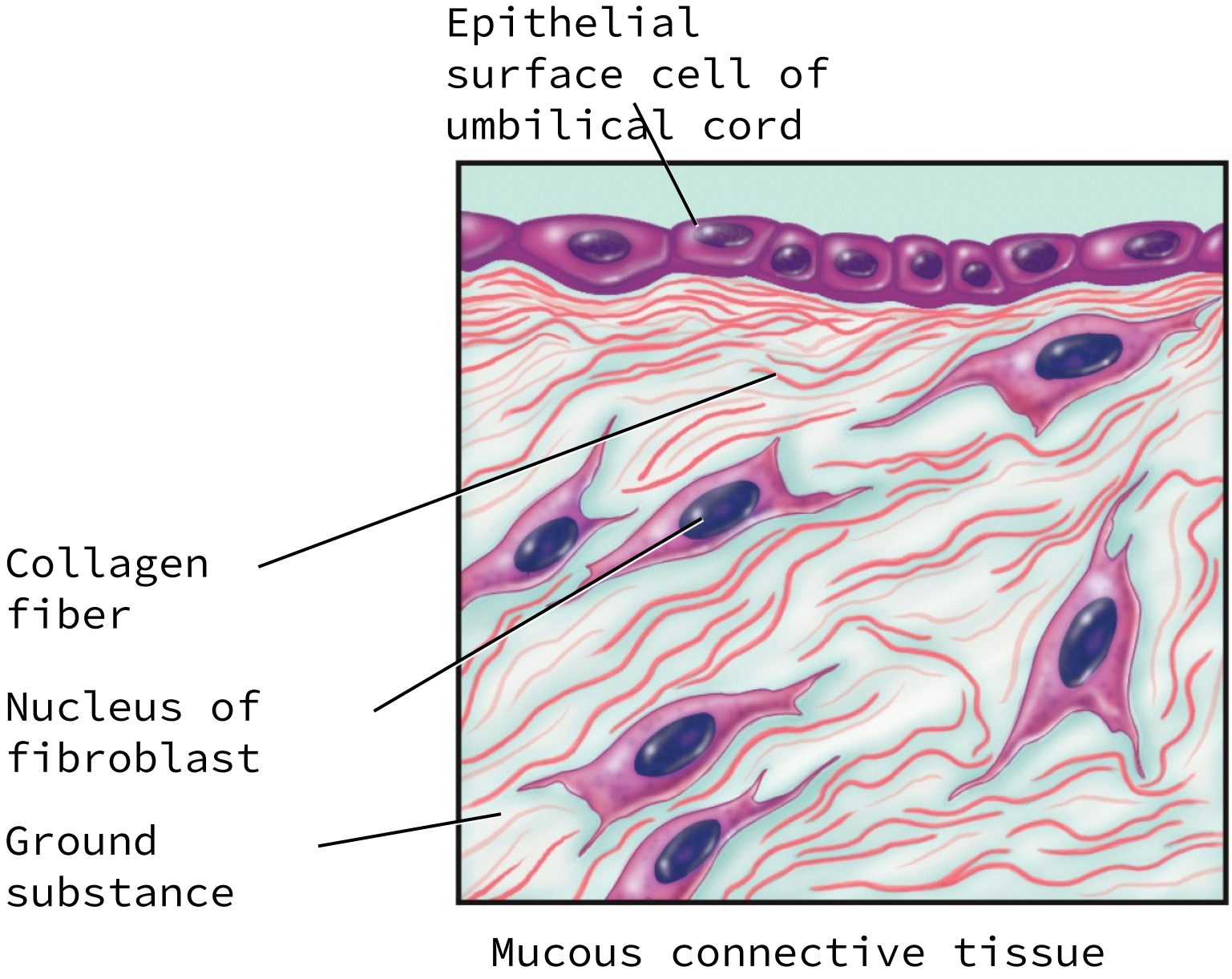

Mucous connective tissue

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Mature connective tissue

- **Loose connective tissue**
  - Areolar connective tissue
  - Adipose tissue
  - Reticular connective tissue
- **Dense connective tissue**
  - Dense regular connective tissue
  - Dense irregular connective tissue
  - Elastic connective tissue
- **Cartilage**
  - Hyaline cartilage
  - Fibrocartilage
  - Elastic cartilage
- **Bone tissue**
- **Liquid connective tissue**
  - Blood tissue
  - Lymph

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Areolar Connective Tissue

TABLE 3.4

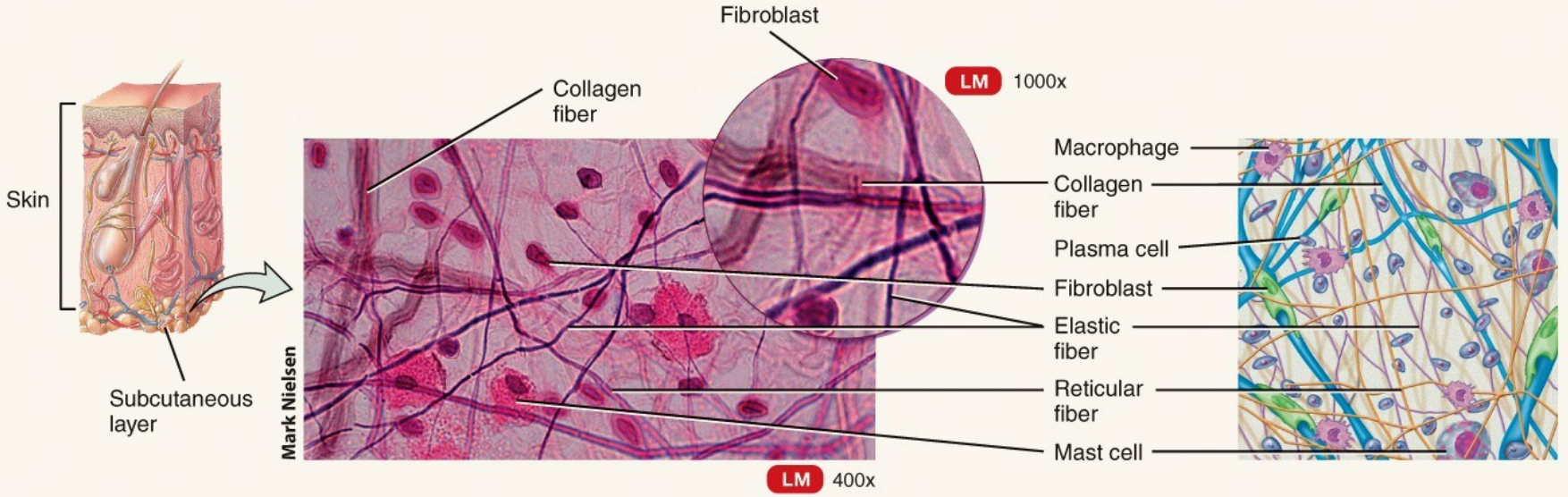
Mature Connective Tissue: Loose Connective Tissue

A. AREOLAR CONNECTIVE TISSUE (a-RĒ-ō-lar; *areol-*=small space)

Description: Consists of fibers (collagen, elastic, and reticular) arranged randomly and several kinds of cells (fibroblasts, macrophages, plasma cells, adipocytes, mast cells, and a few white blood cells) embedded in a semifluid ground substance (hyaluronic acid, chondroitin sulfate, dermatan sulfate, and keratan sulfate).

Location: One of the most widely distributed connective tissues in the body, it is found in the subcutaneous layer deep to skin; papillary (superficial) region of dermis of skin; lamina propria of mucous membranes; and around blood vessels, nerves, and body organs. Called the "packing material" of the body since it is found in and around nearly every structure of the body.

Function: Strength, elasticity, and support.



Sectional view of subcutaneous areolar connective tissue

Areolar connective tissue

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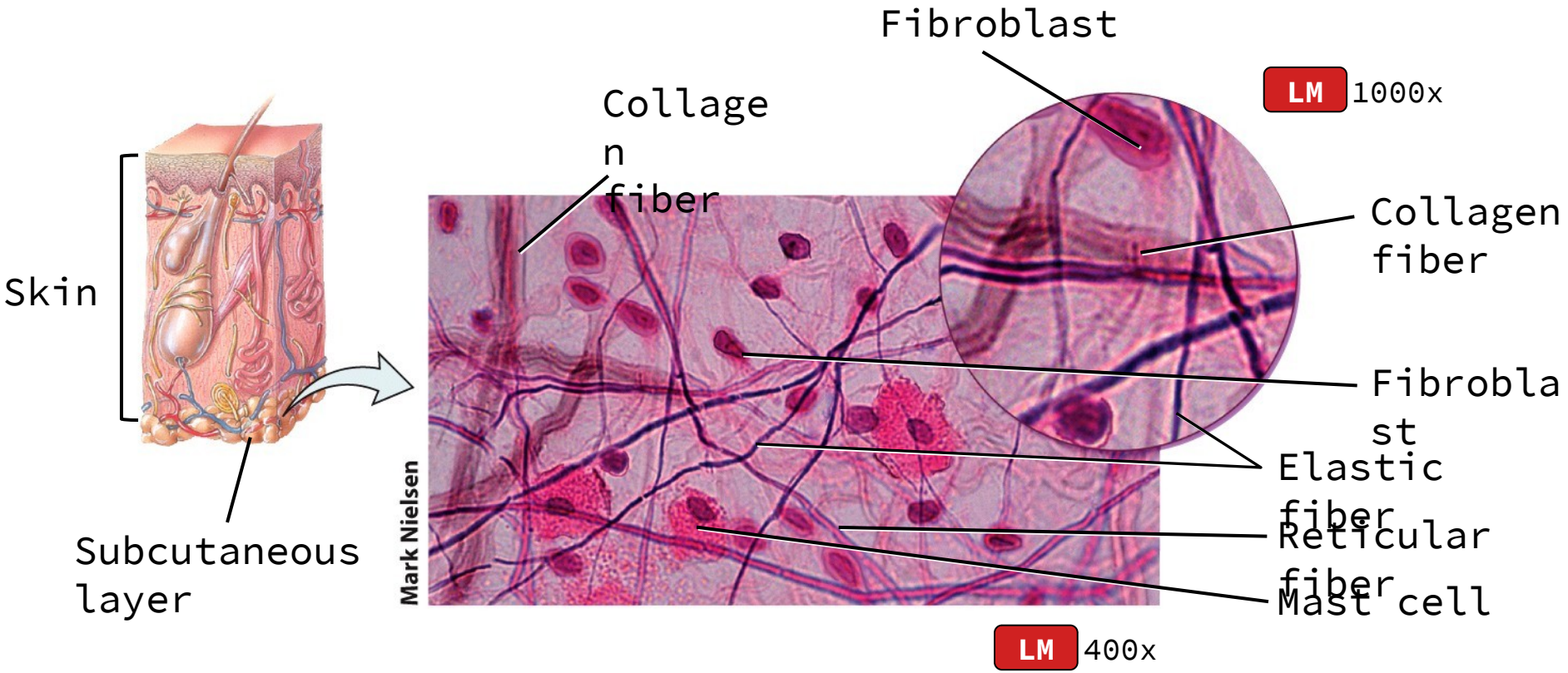

Sectional view of subcutaneous areolar tissue

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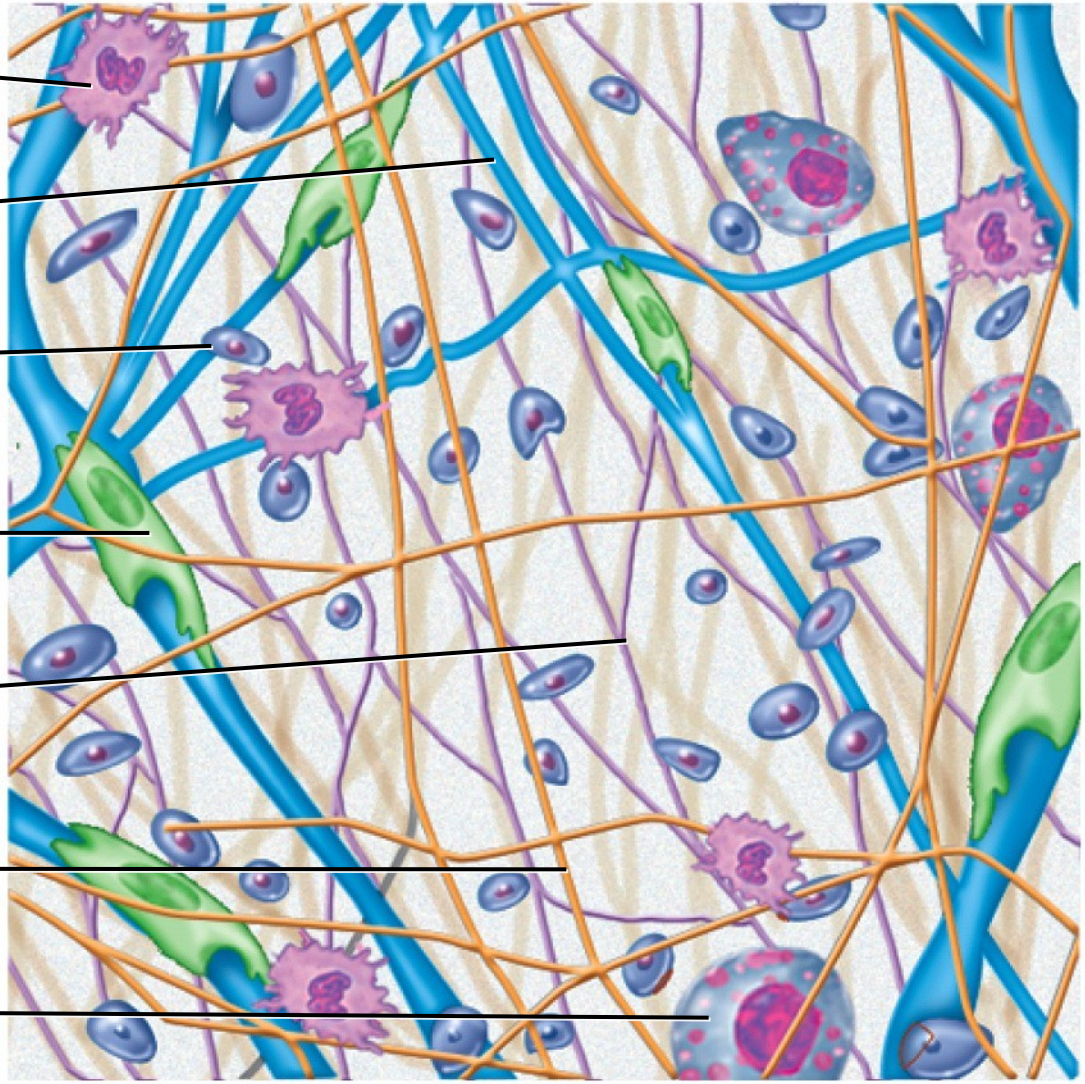

Areolar connective tissue

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Adipose Tissue

TABLE 3.4

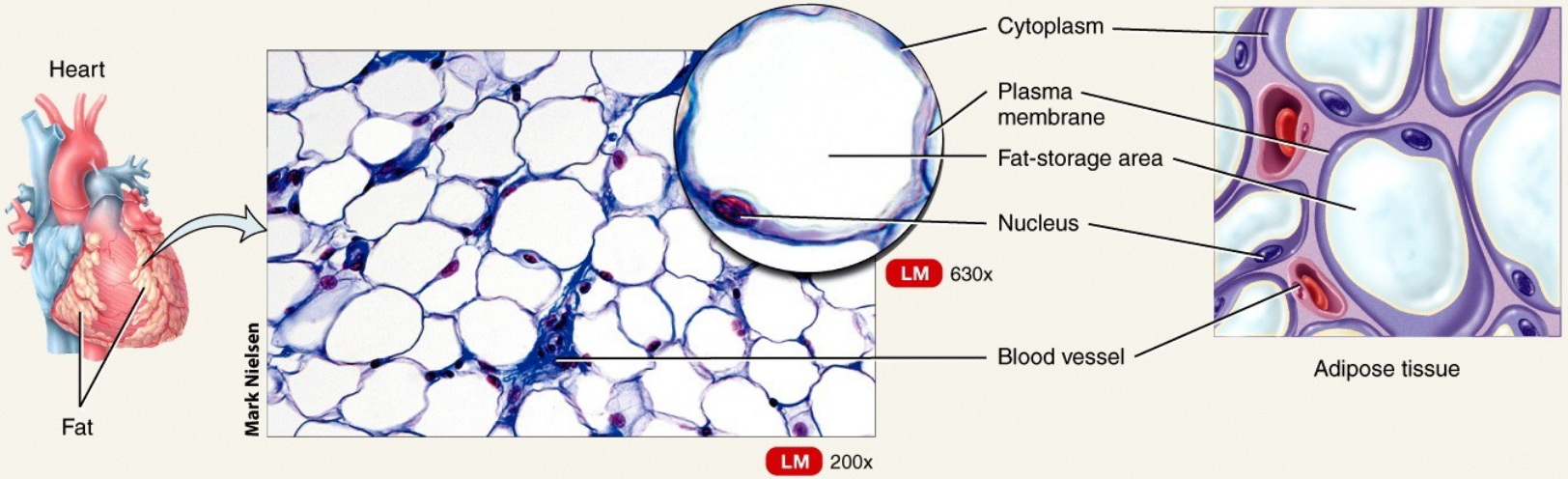
Mature Connective Tissue: Loose Connective Tissue

B. ADIPOSE TISSUE

Description: The cells of adipose tissue, called *adipocytes* (*adipo-*=fat), are specialized for storage of triglycerides (fats) as a large centrally located droplet. Because the cell fills up with a single, large triglyceride droplet, the cytoplasm and nucleus are pushed to the periphery of the cell. As a person gains weight, the amount of adipose tissue increases and new blood vessels form. Thus, an obese person has many more blood vessels than does a lean person, a situation that can cause high blood pressure, since the heart has to work harder. Most adipose tissue in adults is *white adipose tissue*, the type just described. Another type, called *brown adipose tissue* (BAT), obtains its darker color from a very rich blood supply, along with numerous pigmented mitochondria that participate in aerobic cellular respiration. Although BAT is widespread in the fetus and infant, in adults only small amounts are present.

Location: Found wherever areolar connective tissue is located. Subcutaneous layer deep to skin, around heart and kidneys, yellow bone marrow, and padding around joints and behind eyeball in eye socket.

Function: Reduces heat loss through skin, serves as an energy reserve, and supports and protects organs. In newborns, brown adipose tissue generates considerable heat that helps maintain proper body temperature. The heat generated by the many mitochondria is carried away to other body tissues by the extensive blood supply.



Sectional view of adipose tissue showing adipocytes of white fat and details of an adipocyte

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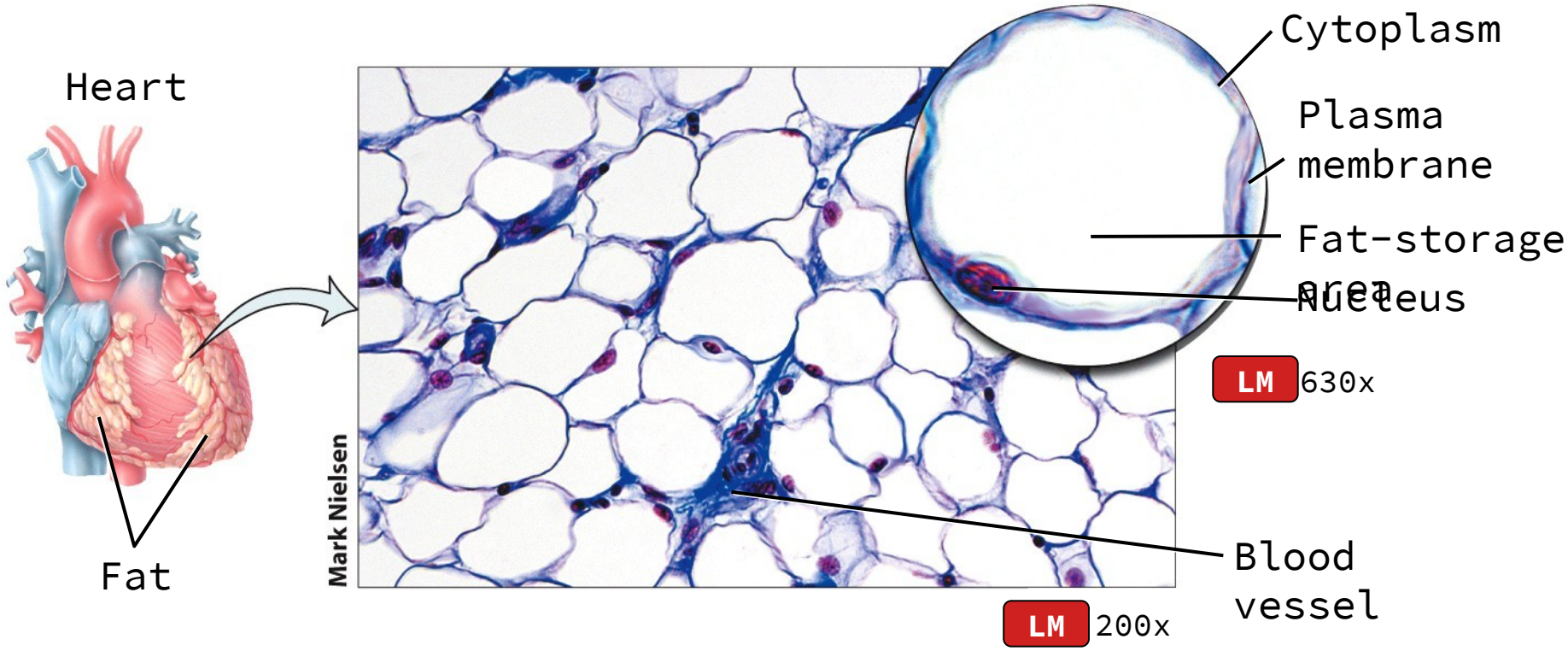

Sectional view of adipose tissue showing adipocytes of white fat and details of an

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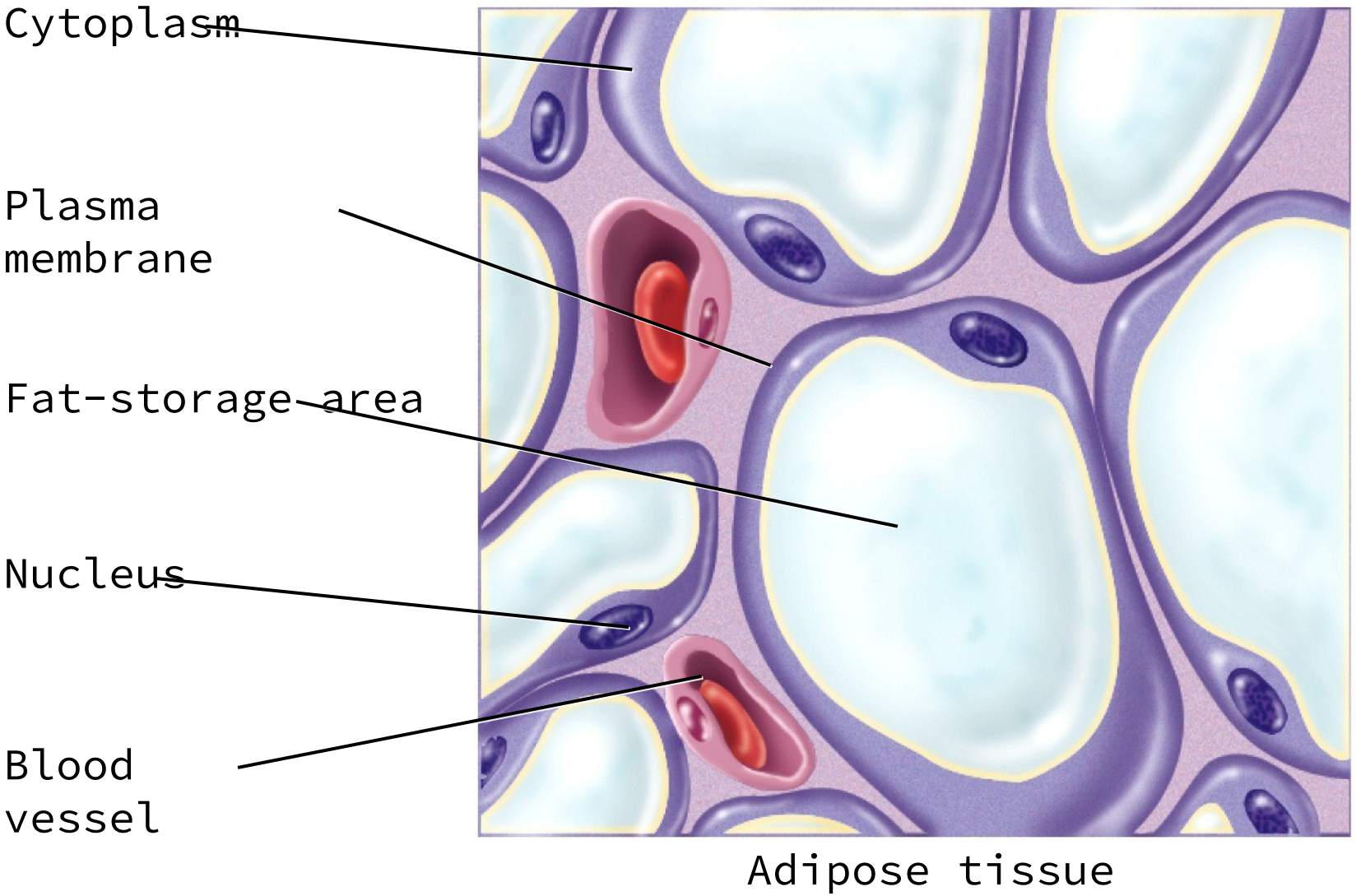

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Clinical Connection

- Liposuction
- Cryolipolysis

Pascal Goetgheluck/Photo Researchers, Inc.

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Abdominal liposuction

Clinical Connection

Suctioning out small amounts of adipose tissue from various areas of the body.
After an incision is made in the skin, the fat is removed through a stainless steel tube, called a cannula, with the assistance of a powerful
vacuum pressure unit that suctions out the fat. The technique can be
used as a body-contouring procedure in regions such as the thighs,
buttocks, arms, breasts, and abdomen, and to transfer fat to another
area of the body. Postsurgical complications that may develop include
fat that may enter blood vessels broken during the procedure and obstruct
blood flow, infection, loss of feeling in the area, fluid depletion, injury to internal structures, and severe postoperative pain.

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Reticular Connective Tissue

TABLE 3.4

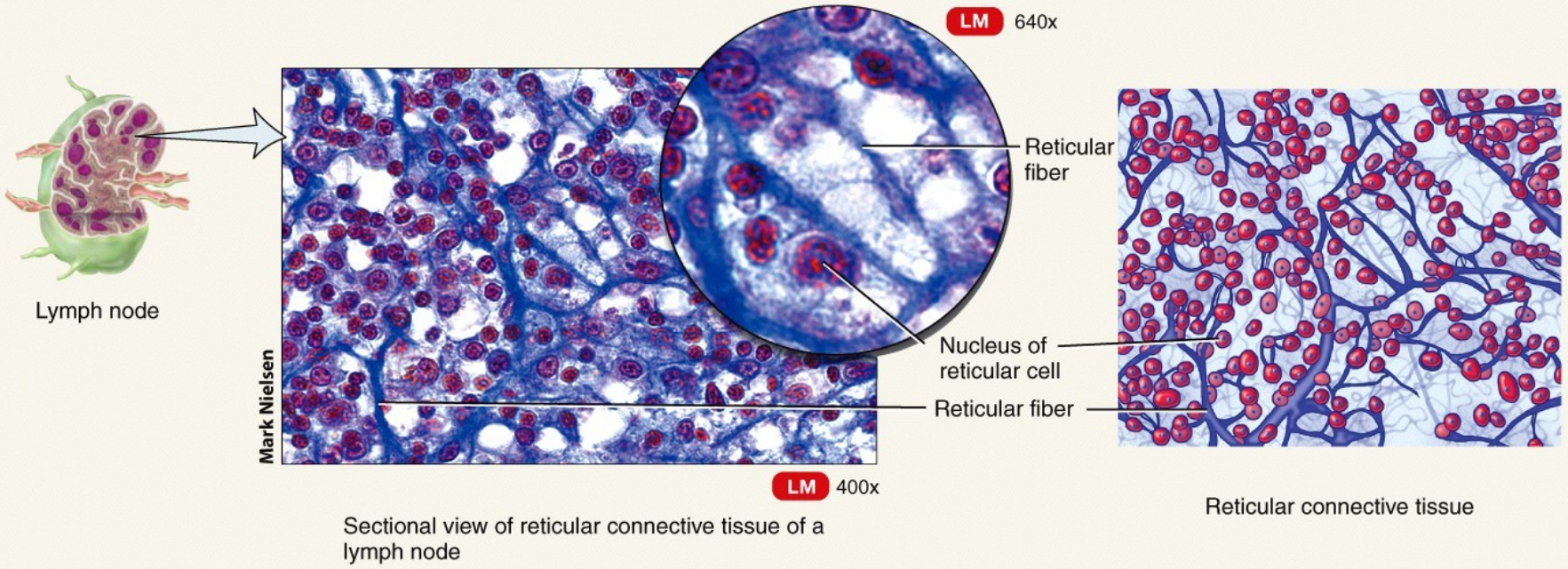
Mature Connective Tissue: Loose Connective Tissue

C. RETICULAR CONNECTIVE TISSUE

Description: Consists of fine interlacing network of reticular fibers (a thin form of collagen fiber) and reticular cells.

Location: Stroma (supporting framework) of liver, spleen, lymph nodes; red bone marrow, which gives rise to blood cells; reticular lamina of the basement membrane; and around blood vessels and muscles.

Function: Forms stroma of organs; binds together smooth muscle tissue cells; filters and removes worn-out blood cells in the spleen and microbes in lymph nodes.



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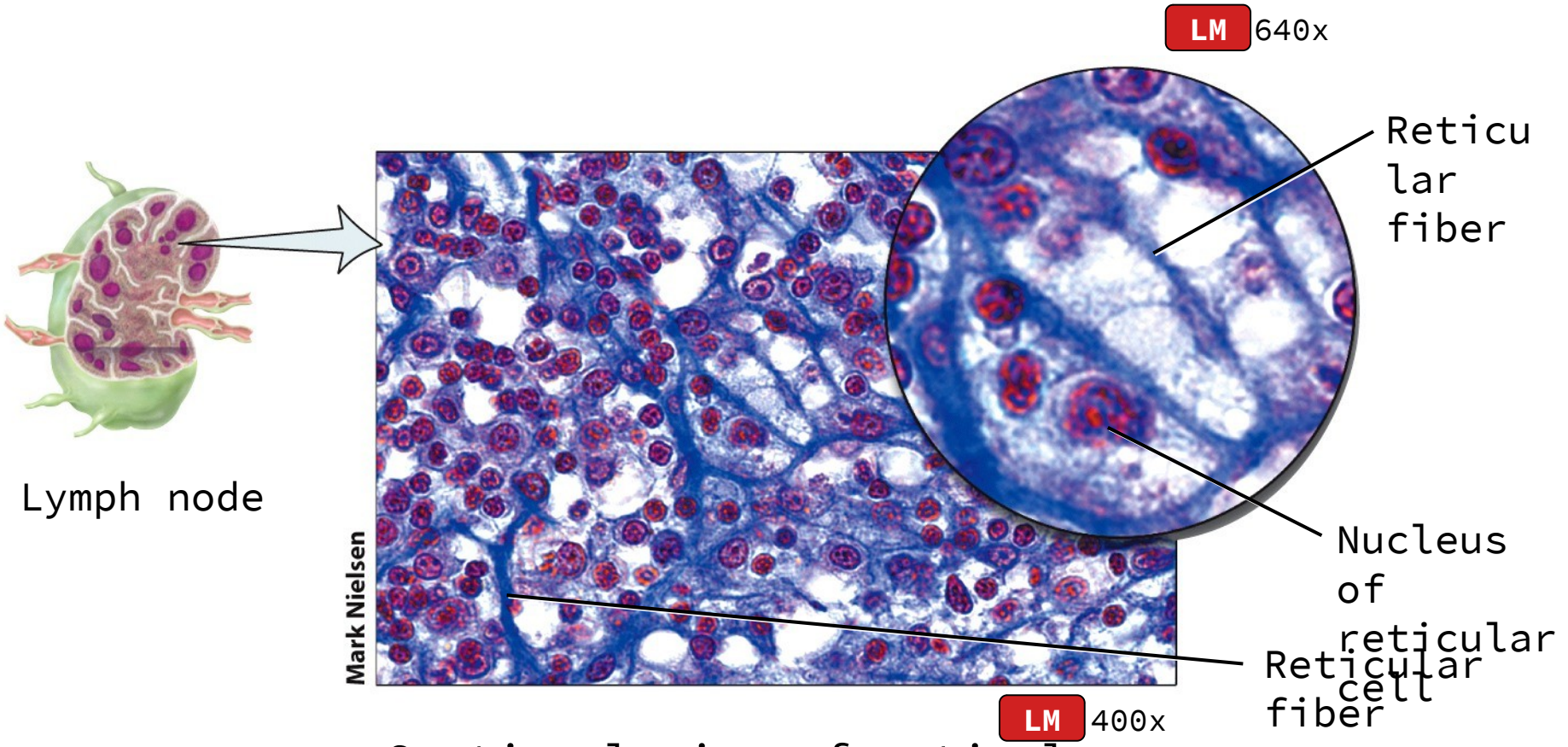

Sectional view of reticular connective tissue of a lymph

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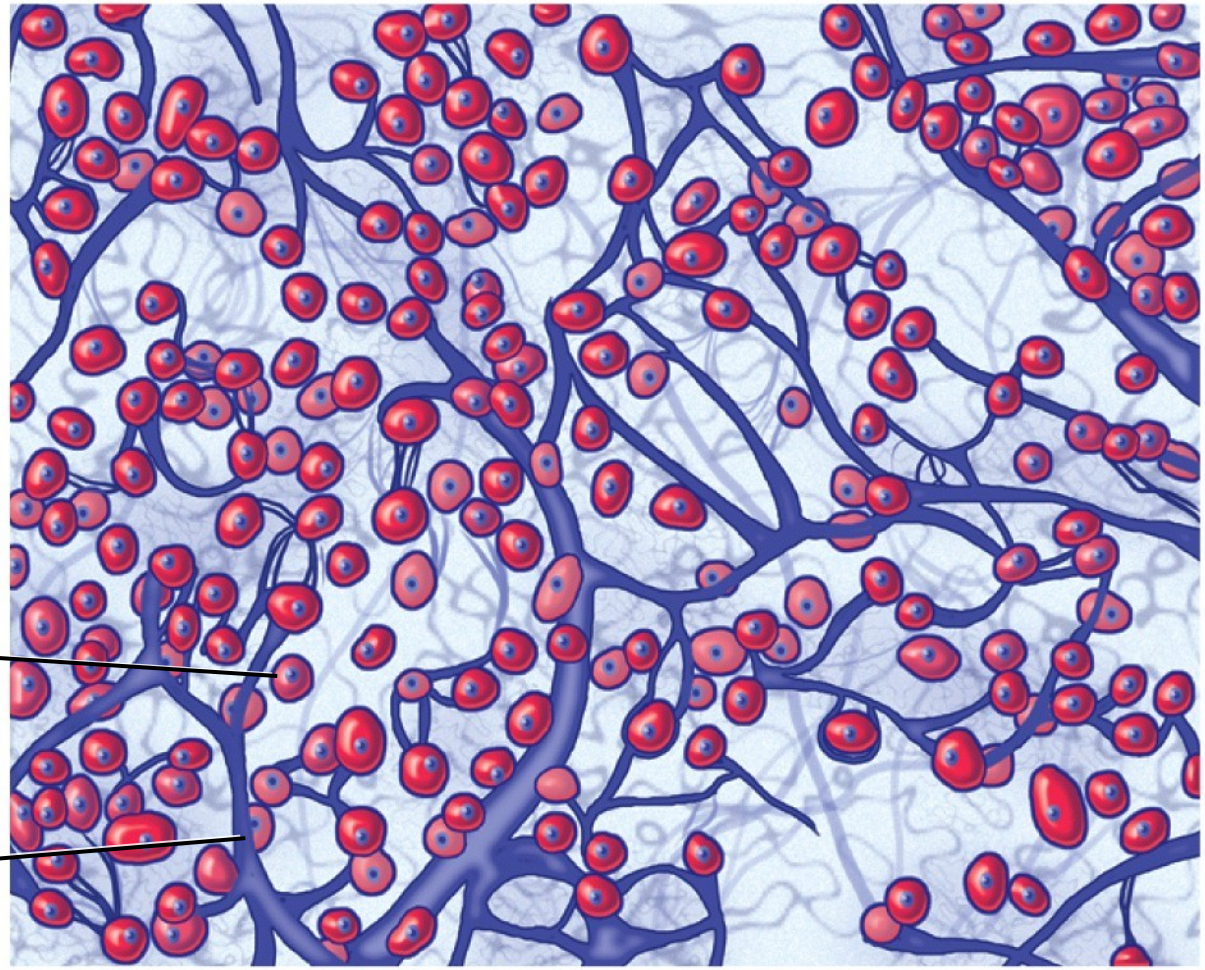

Reticular connective tissue

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Mature connective tissue

- Loose connective tissue
  - Areolar connective tissue
  - Adipose tissue
  - Reticular connective tissue
- Dense connective tissue
  - Dense regular connective tissue
  - Dense irregular connective tissue
  - Elastic connective tissue
- Cartilage
  - Hyaline cartilage
  - Fibrocartilage
  - Elastic cartilage
- Bone tissue
- Liquid connective tissue
  - Blood tissue
  - Lymph

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Dense Regular Connective Tissue

TABLE 3.5

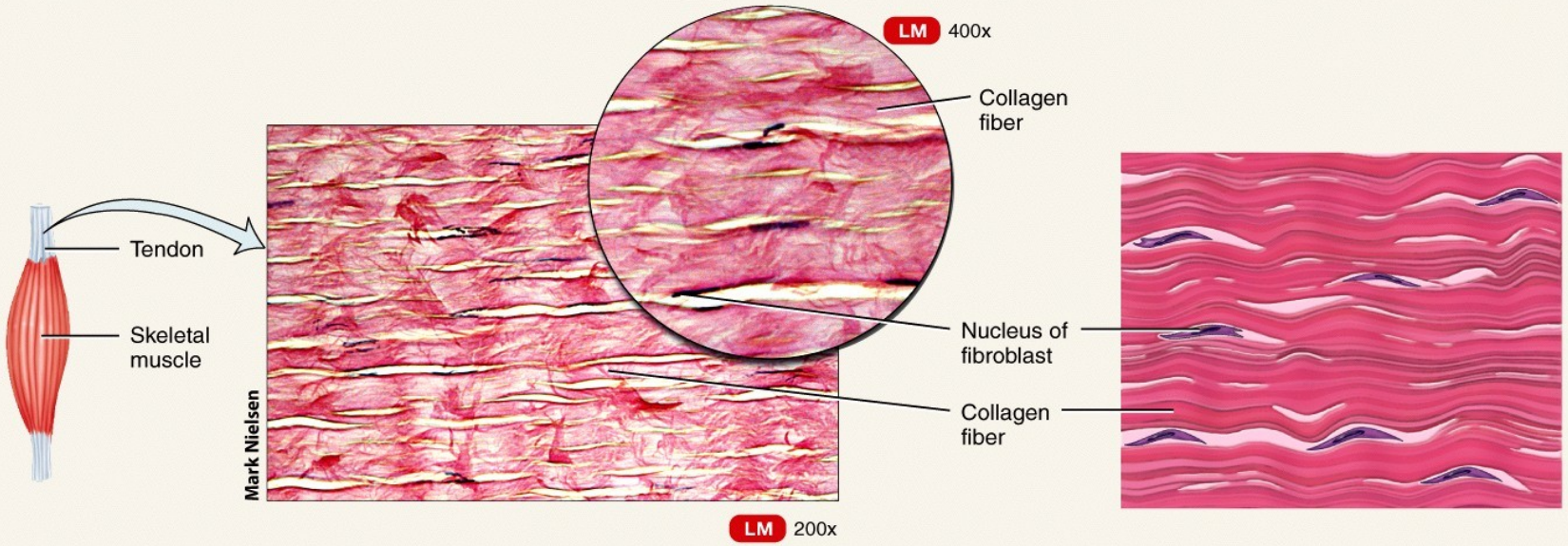
Mature Connective Tissue: Dense Connective Tissue

A. DENSE REGULAR CONNECTIVE TISSUE

Description: Extracellular matrix looks shiny white. Consists mainly of collagen fibers *regularly* arranged in bundles with fibroblasts present in rows between the bundles. The collagen fibers are not living (they are protein structures secreted by the fibroblasts); since tendons and ligaments have very few blood vessels, they are slow to heal following damage.

Location: Forms tendons (attach muscle to bone), most ligaments (attach bone to bone), and aponeuroses (sheetlike tendons that attach muscle to muscle or muscle to bone).

Function: Provides strong attachment between various structures. The tissue structure withstands pulling (tension) along the long axis of the fibers.



Sectional view of dense regular connective tissue of a tendon

Dense regular connective tissue

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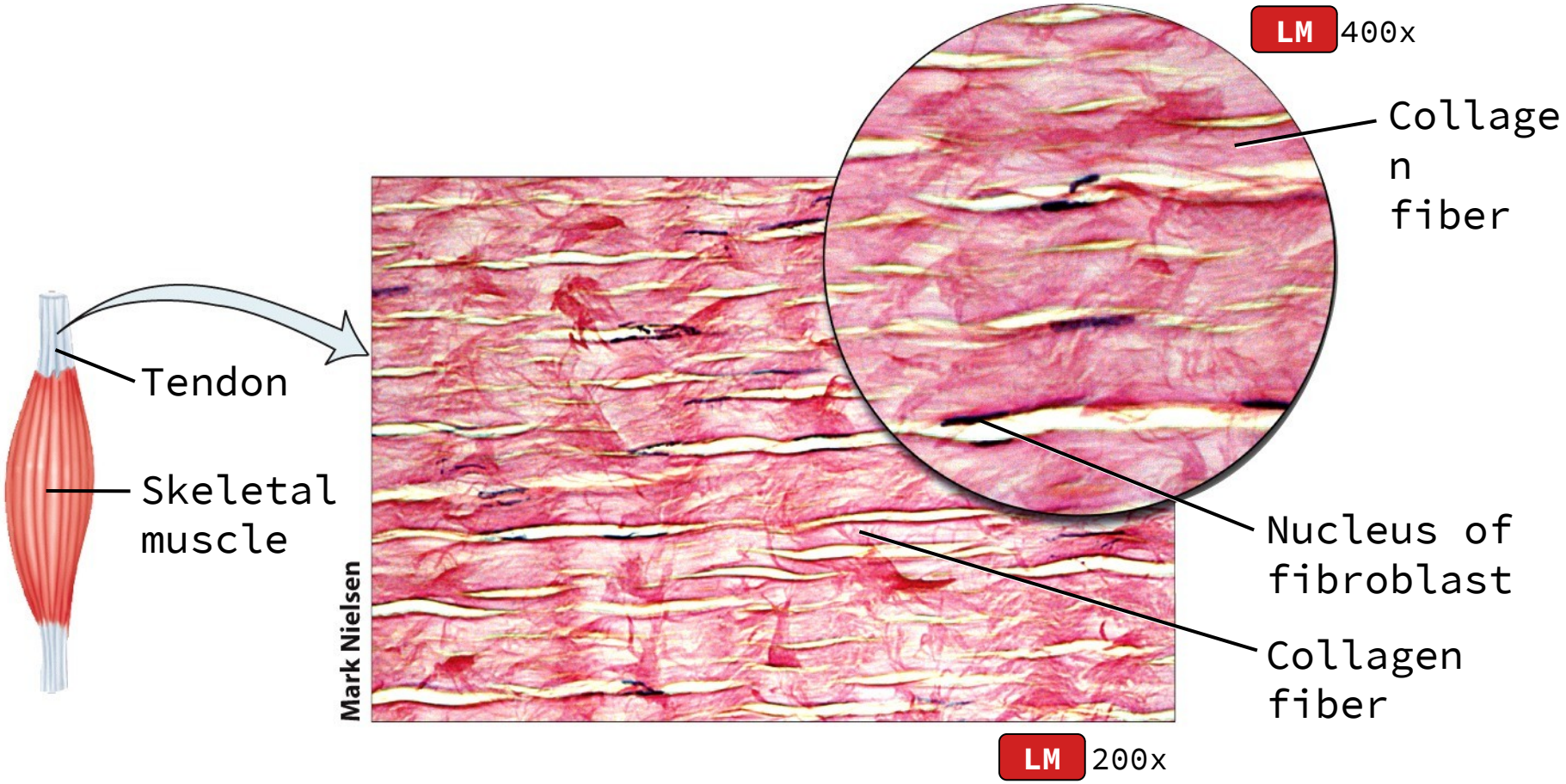

Sectional view of dense regular connective tissue
ɛndon

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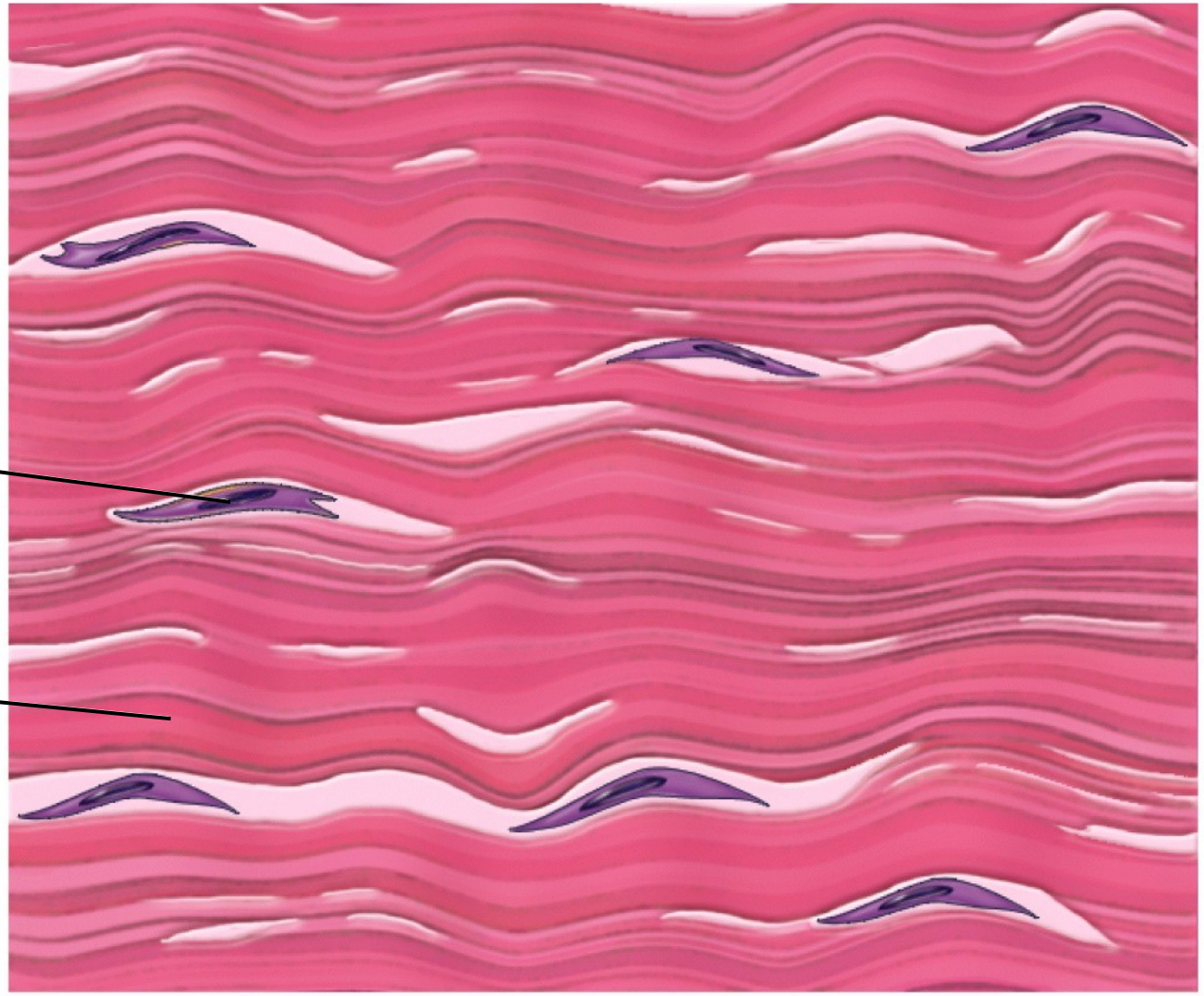

Dense regular connective tissue

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Dense Irregular Connective Tissue

TABLE 3.5

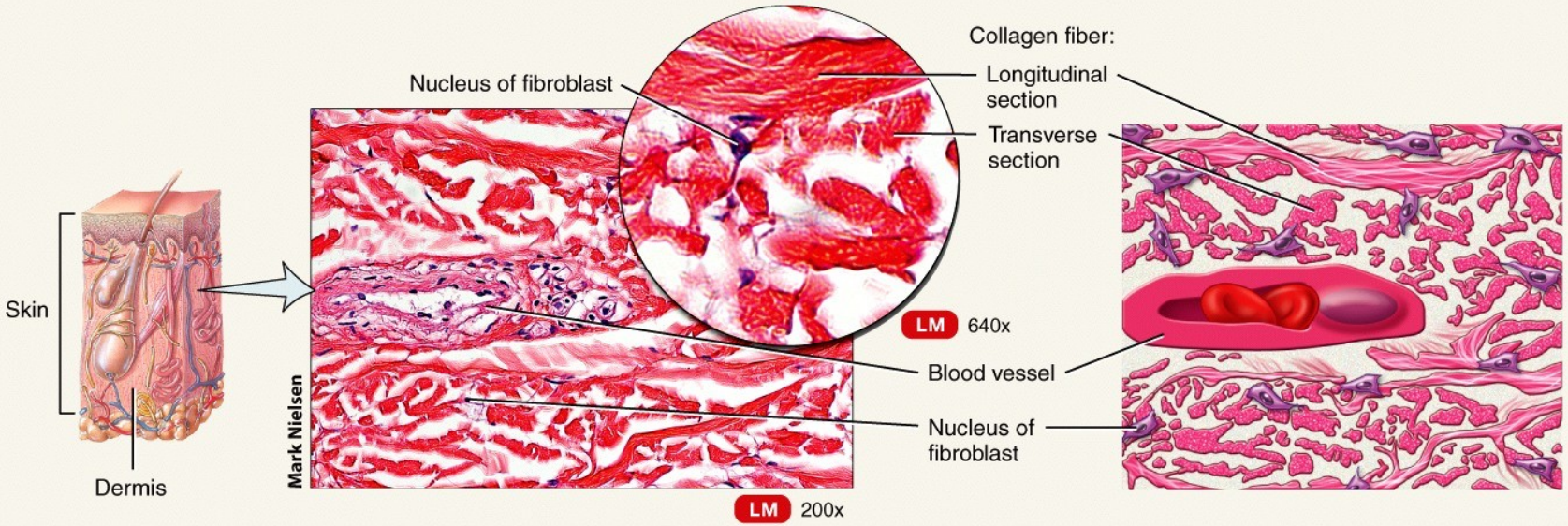
Mature Connective Tissue: Dense Connective Tissue

B. DENSE IRREGULAR CONNECTIVE TISSUE

Description: Contains tightly packed, woven meshes of collagen fibers that are usually *irregularly* arranged.

Location: This tissue often occurs in sheets, such as fasciae (tissue beneath skin and around muscles and other organs), reticular (deeper) region of dermis of skin, fibrous pericardium of heart, periosteum of bone, perichondrium of cartilage, joint capsules, membrane capsules around various organs (kidneys, liver, testes, lymph nodes). Also found in heart valves.

Function: Provides tensile (pulling) strength in many directions.



Sectional view of dense irregular connective tissue of reticular region of dermis

Dense irregular connective tissue

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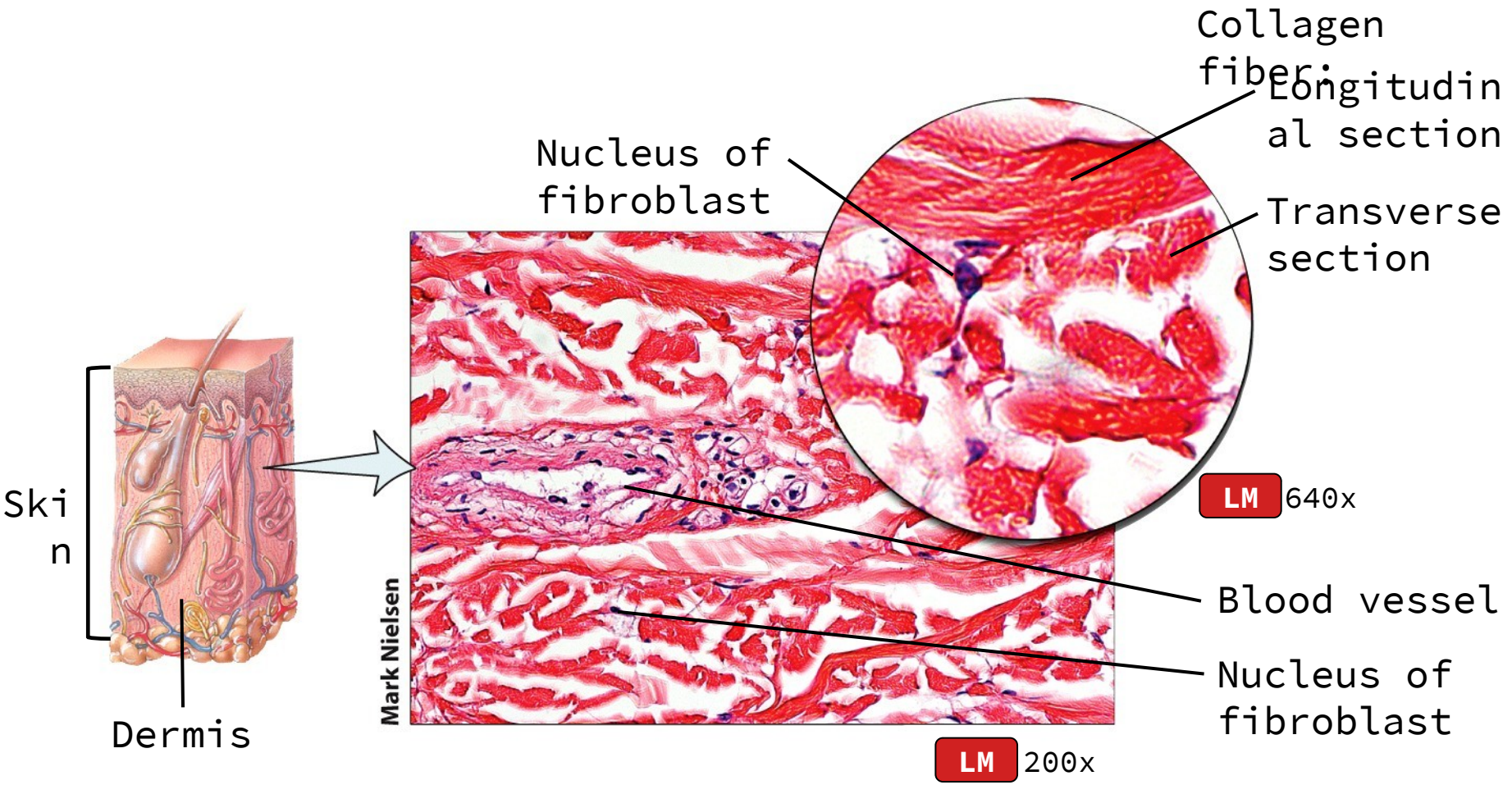

Sectional view of dense irregular connective tissue of reticular region of dermis

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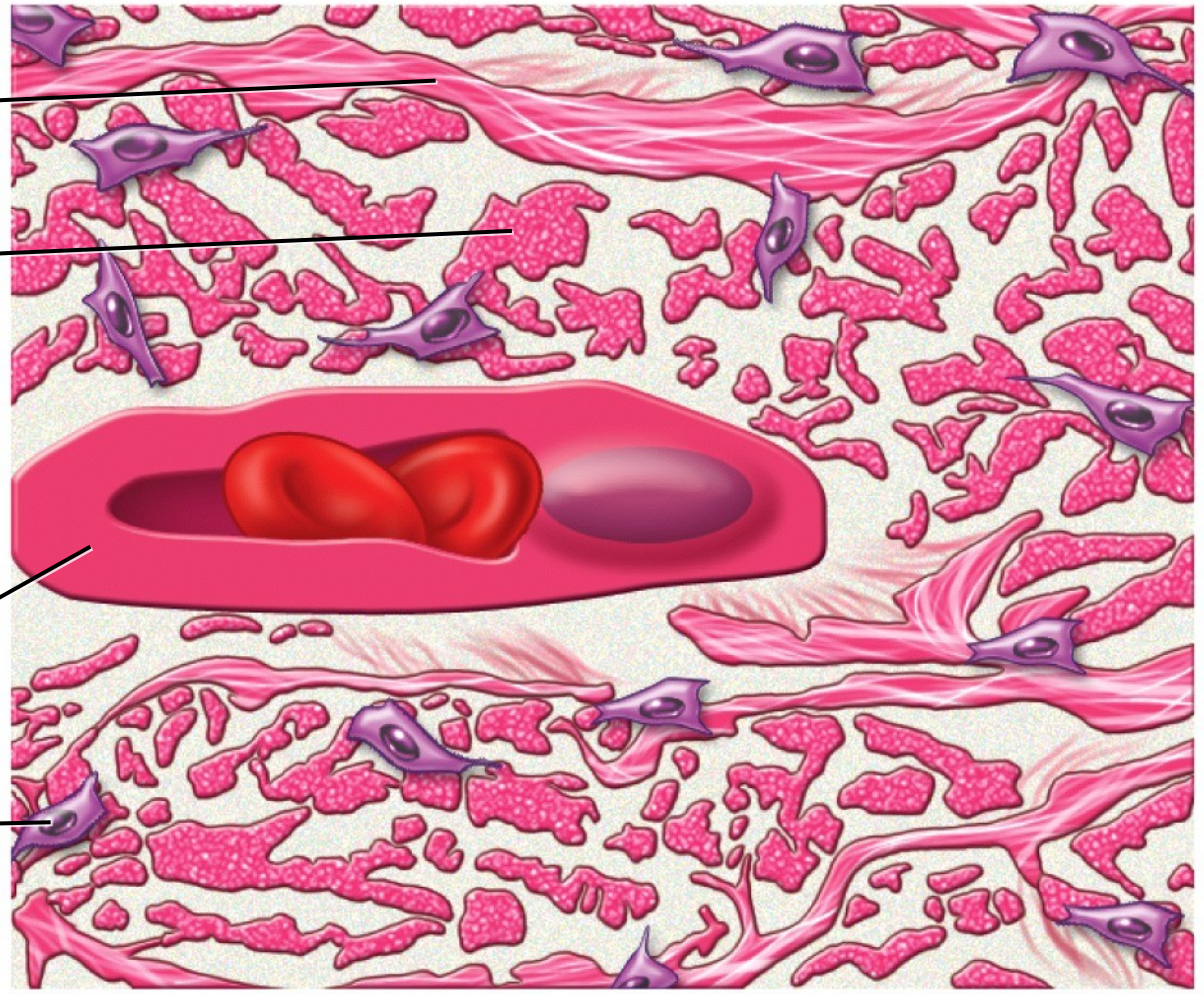

Dense irregular connective tissue

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Elastic Connective Tissue

TABLE 3.5

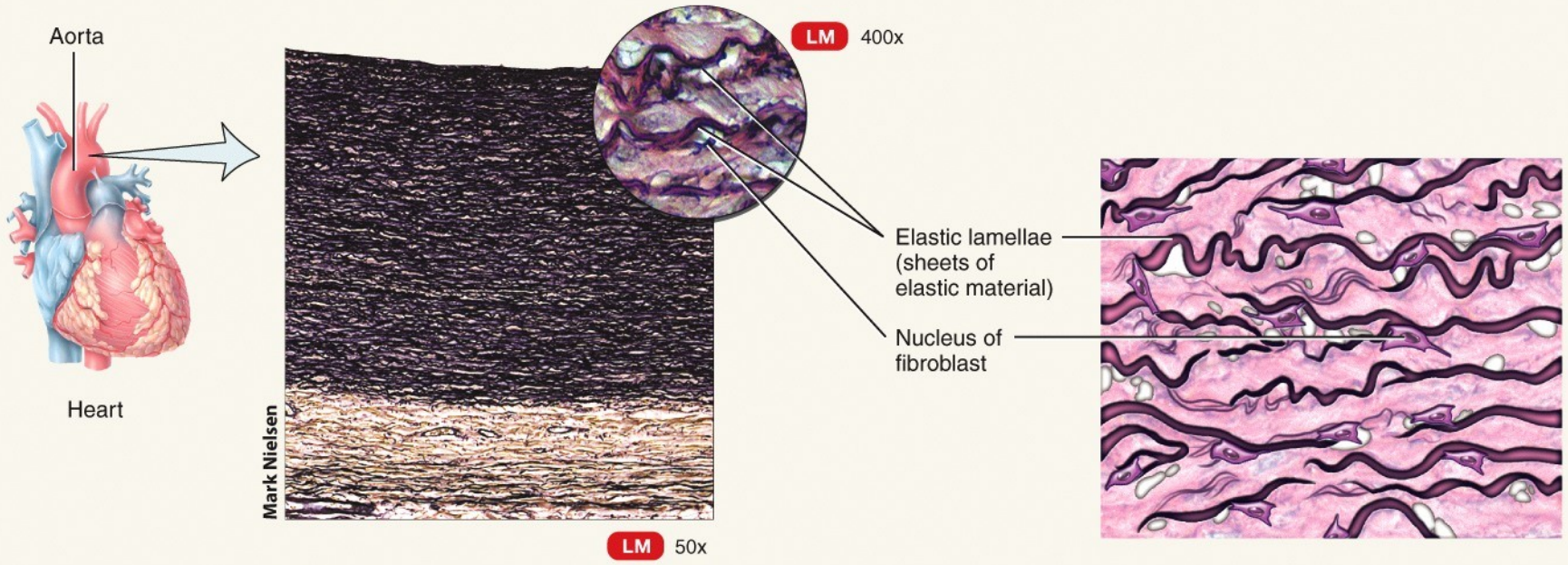
Mature Connective Tissue: Dense Connective Tissue

C. ELASTIC CONNECTIVE TISSUE

Description: Consists predominantly of elastic fibers with fibroblasts in spaces between the fibers. The unstained tissue has a yellowish color.

Location: Lung tissue, walls of elastic arteries, trachea, bronchial tubes, true vocal cords, suspensory ligaments of penis, and some ligaments between vertebrae.

Function: Allows stretching of various organs. Elastic connective tissue is quite strong and can recoil to its original shape after being stretched. Elasticity is important to the normal functioning of lung tissue, which recoils as you exhale, and elastic arteries, which recoil between heartbeats to help maintain blood flow.



Sectional view of elastic connective tissue of aorta

Elastic connective tissue

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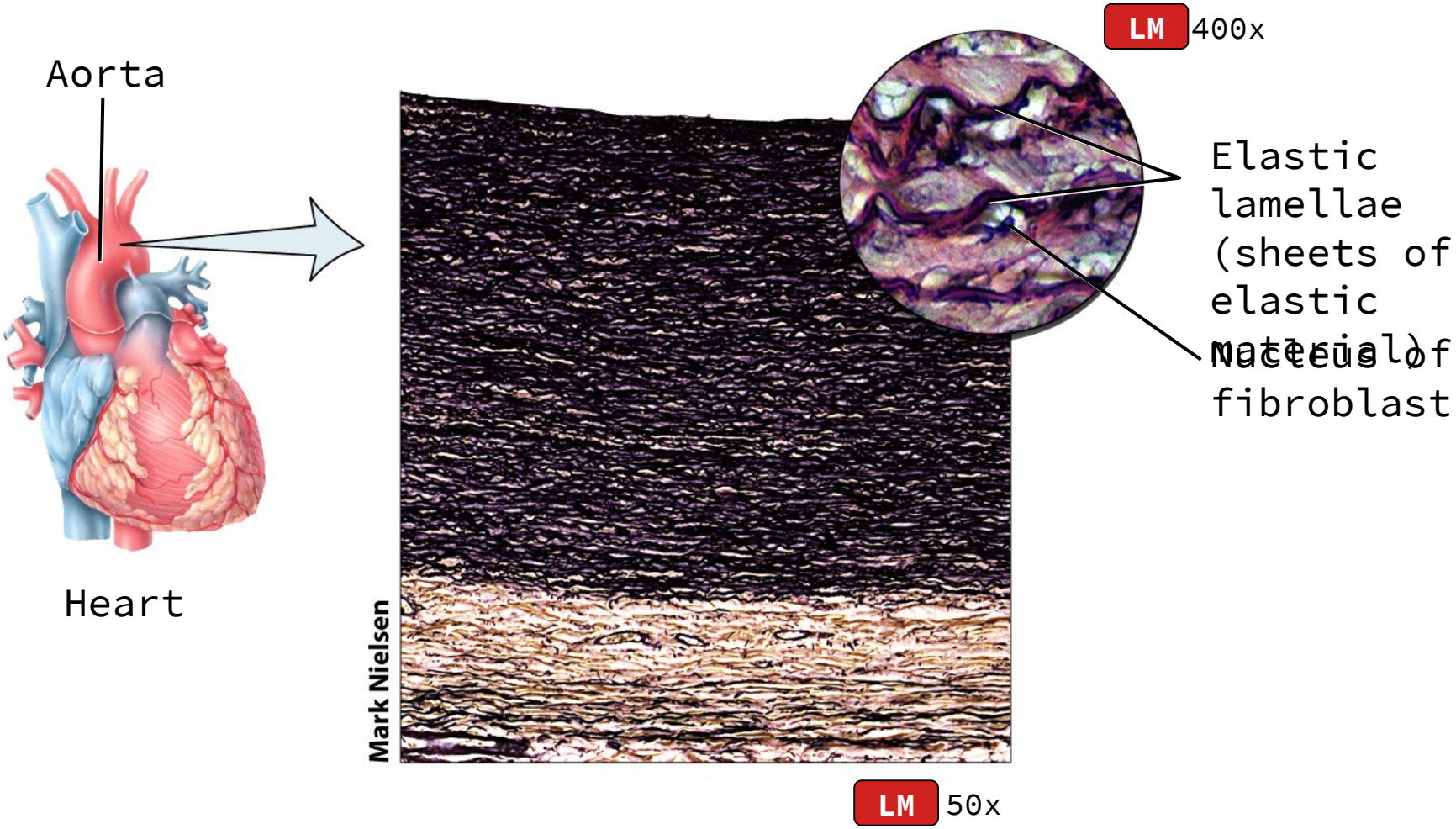

Sectional view of elastic connective tissue of aorta

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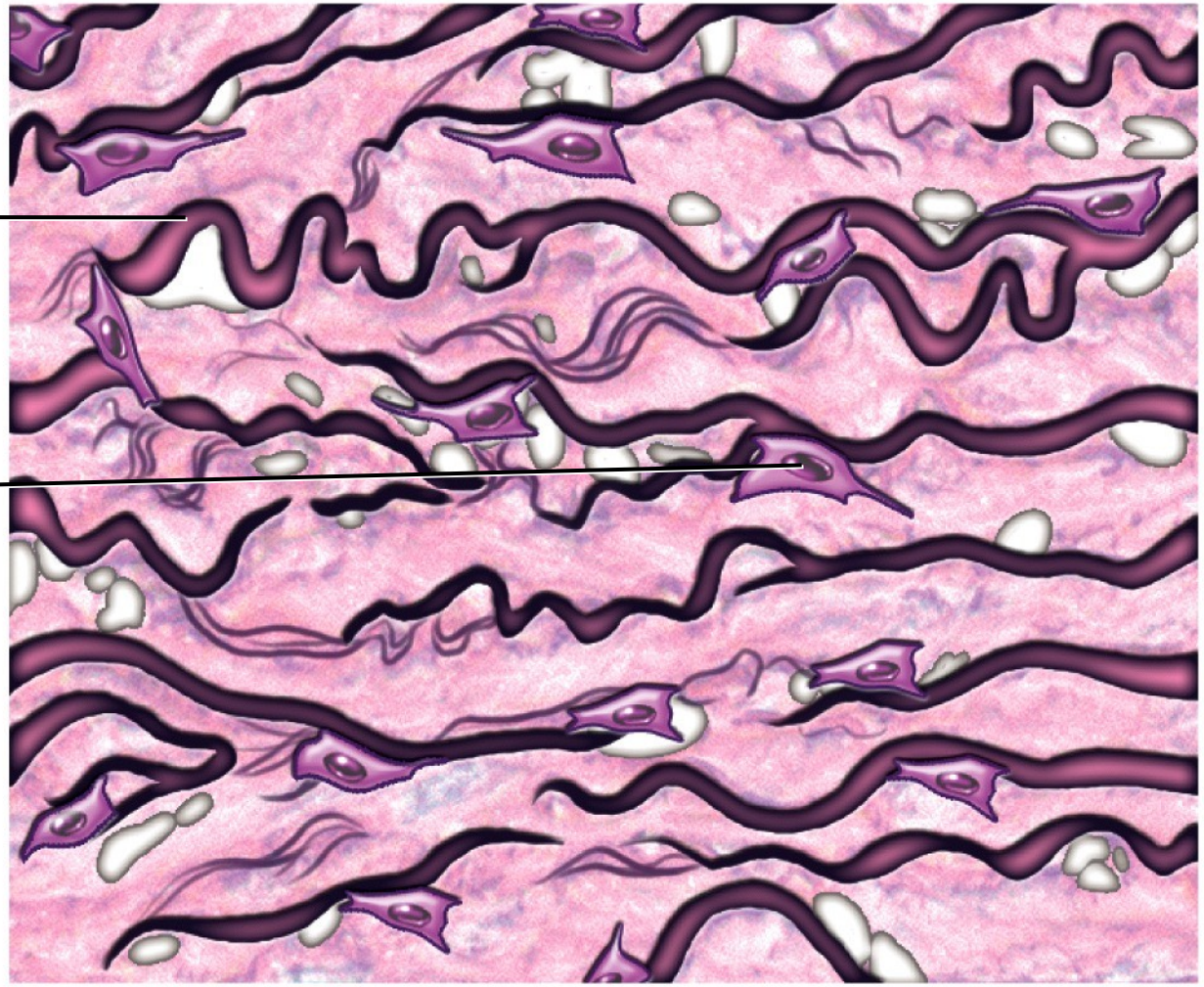
Elastic lamellae (sheets of elastic material)

Nucleus of fibroblast



Elastic connective tissue

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Mature connective tissue

- Loose connective tissue
  - Areolar connective tissue
  - Adipose tissue
  - Reticular connective tissue
- Dense connective tissue
  - Dense regular connective tissue
  - Dense irregular connective tissue
  - Elastic connective tissue
- Cartilage
  - Hyaline cartilage
  - Fibrocartilage
  - Elastic cartilage
- Bone tissue
- Liquid connective tissue
  - Blood tissue
  - Lymph

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Cartilage

- consists of a dense network of collagen fibers and elastic fibers firmly embedded in chondroitin sulfate (giving it *resilience:* ability to assume its original shape after deformation)
- endures considerably more stress than loose and dense CT due to its collagen fibers
- cartilage has few cells and large quantities of extracellular matrix
- unlike other CT, it is avascular (it secretes an *antiangiogenesis* factor - substance that prevents blood vessel growth) and has no nerve supply
- mature cartilage - **chondrocytes** occur singly or in groups within spaces called **lacunae** in the extracellular matrix.
- A covering of dense irregular connective tissue called the **perichondrium** surrounds the surface of most cartilage, contains blood vessels and nerves, and is the source of new cartilage cells.

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Cartilage

- support tissue in the body
- precursor to bone, and forms almost the entire embryonic skeleton
- although bone gradually replaces cartilage during further development, cartilage persists after birth as growth plates (epiphyseal plates) that allow bones to increase in length during the growing years
- also persists throughout life as the lubricated articular surfaces of most joints

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Hyaline Cartilage

TABLE 3.6

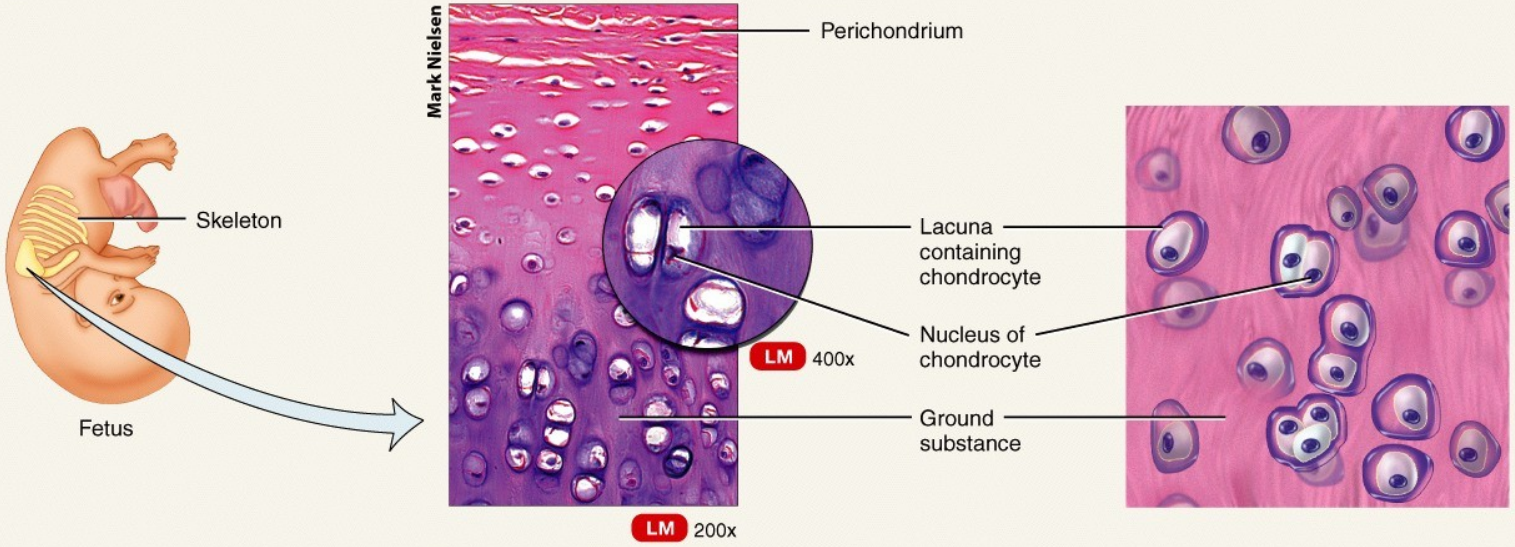
Mature Connective Tissue: Cartilage

A. HYALINE CARTILAGE

Description: Hyaline (*hyalinos*=glassy) cartilage contains a resilient gel as its ground substance and appears in the body as a bluish-white, shiny substance (can stain pink or purple when prepared for microscopic examination). The fine collagen fibers are not visible with ordinary staining techniques, and prominent chondrocytes are found in lacunae. Most hyaline cartilage is surrounded by a perichondrium. The exceptions are the articular cartilage in joints and the cartilage of epiphyseal plates, the regions where bones lengthen as a person grows.

Location: Most abundant cartilage in the body, it is found at the ends of long bones, anterior ends of ribs, nose, parts of larynx, trachea, bronchi, bronchial tubes, and embryonic and fetal skeleton.

Function: Provides smooth surfaces for movement at joints, as well as flexibility and support. It is the weakest of the three types of cartilage and can be fractured.



Sectional view of hyaline cartilage of a developing fetal bone

Hyaline cartilage

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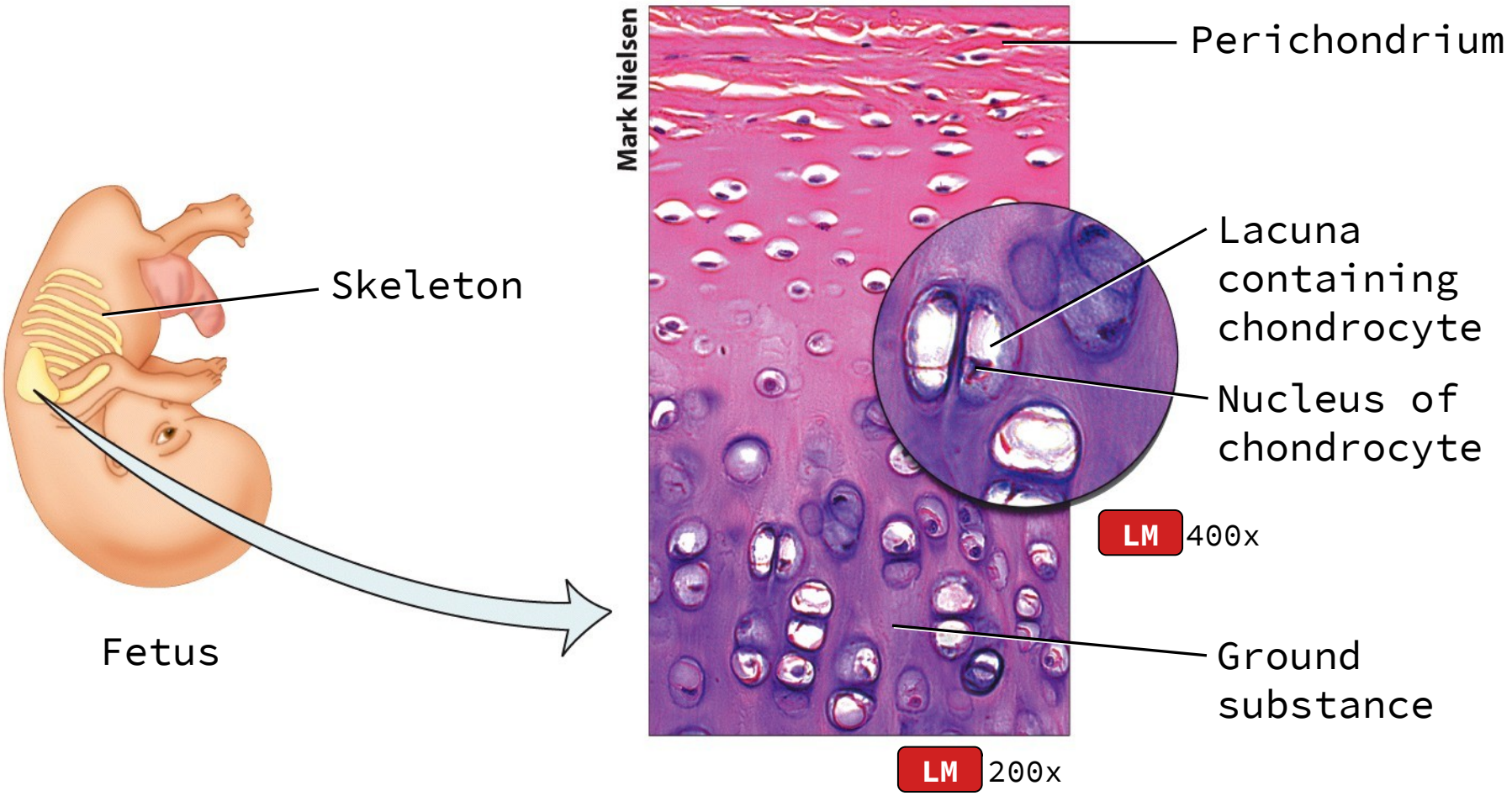

Sectional view of hyaline cartilage of a developing fetal bone

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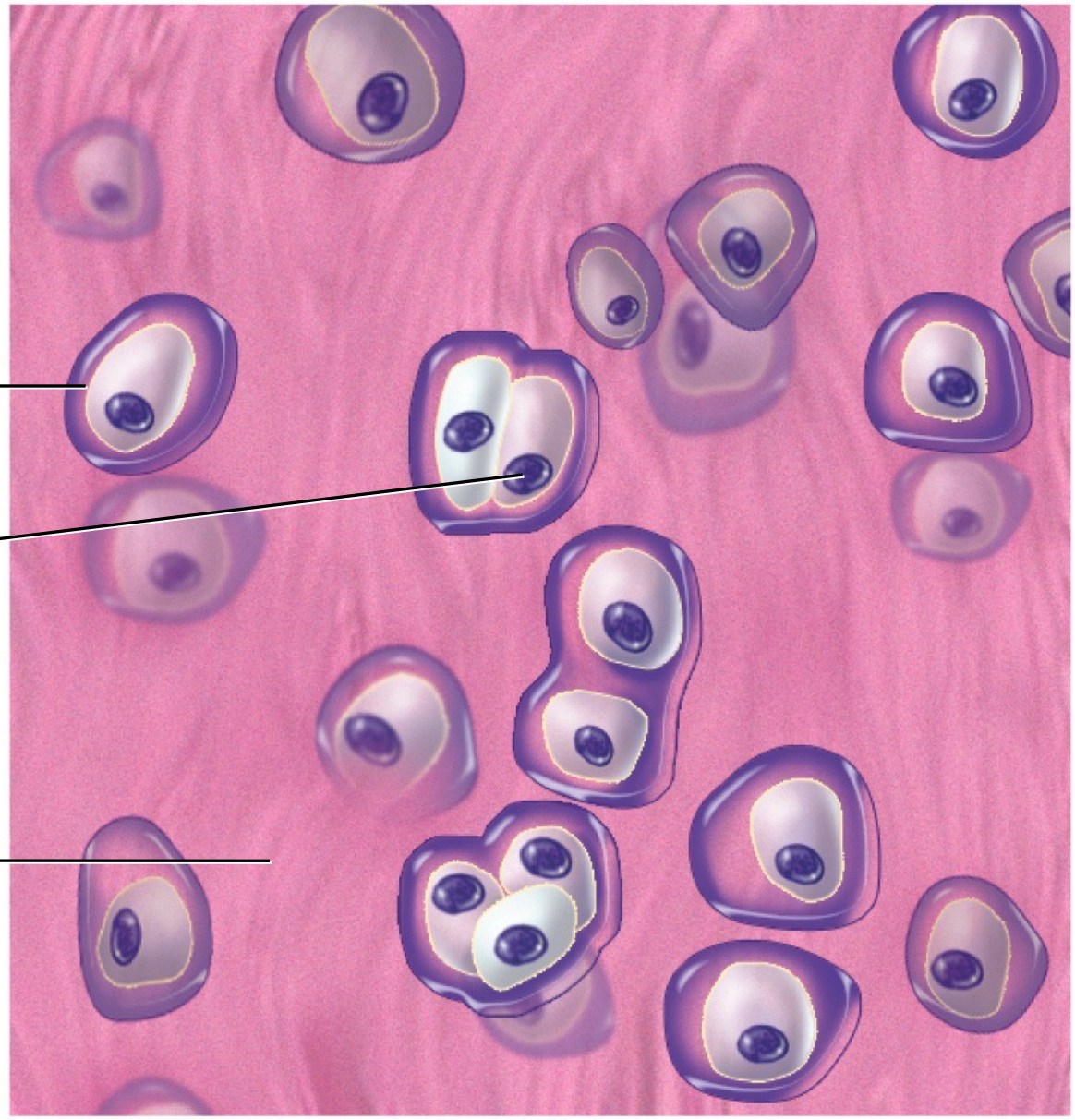

Hyaline cartilage

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Fibrocartilage

TABLE 3.6

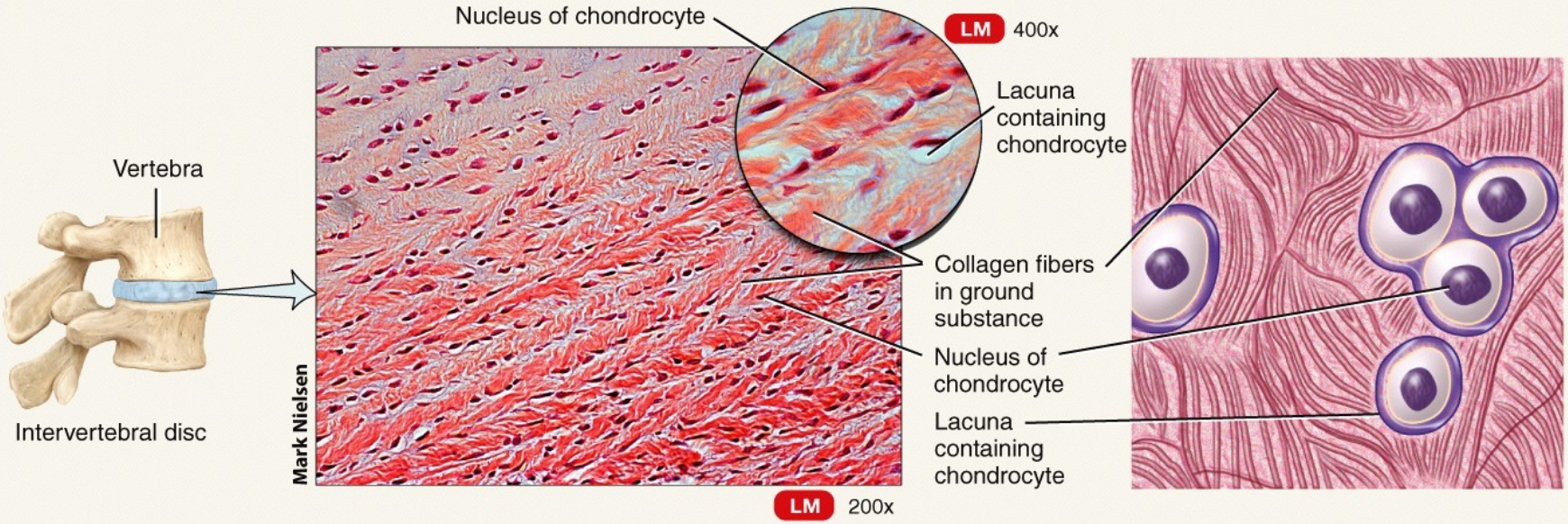
Mature Connective Tissue: Cartilage

B. FIBROCARTILAGE

Description: Chondrocytes are scattered among clearly visible thick bundles of collagen fibers within the extracellular matrix of fibrocartilage. Fibrocartilage lacks a perichondrium.

Location: Pubic symphysis (point where hip bones join anteriorly), intervertebral discs (discs between vertebrae), menisci (cartilage pads) of knee, and portions of tendons that insert into cartilage.

Function: Support and joining structures together. With a combination of strength and rigidity, this tissue is the strongest of the three types of cartilage.



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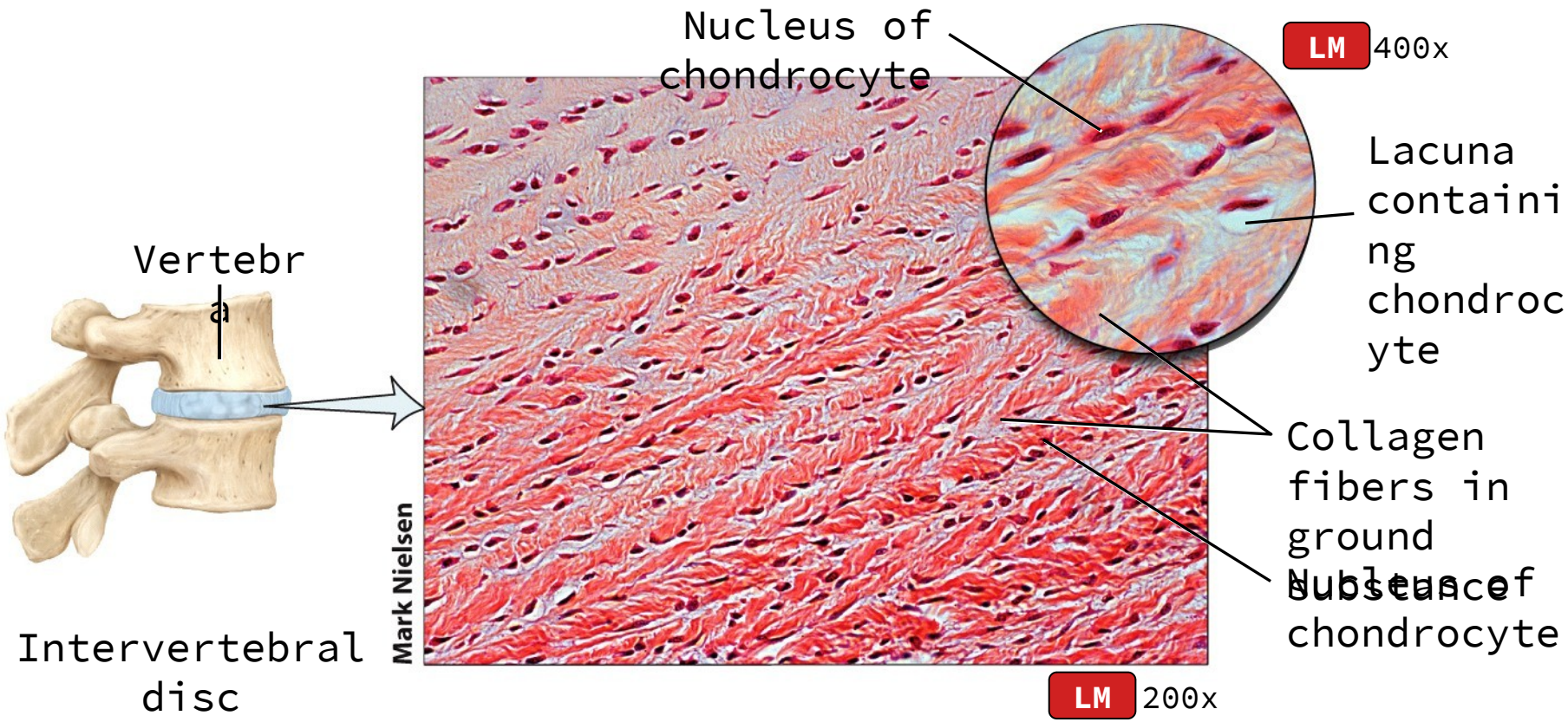

Sectional view of fibrocartilage of tervertebral disc

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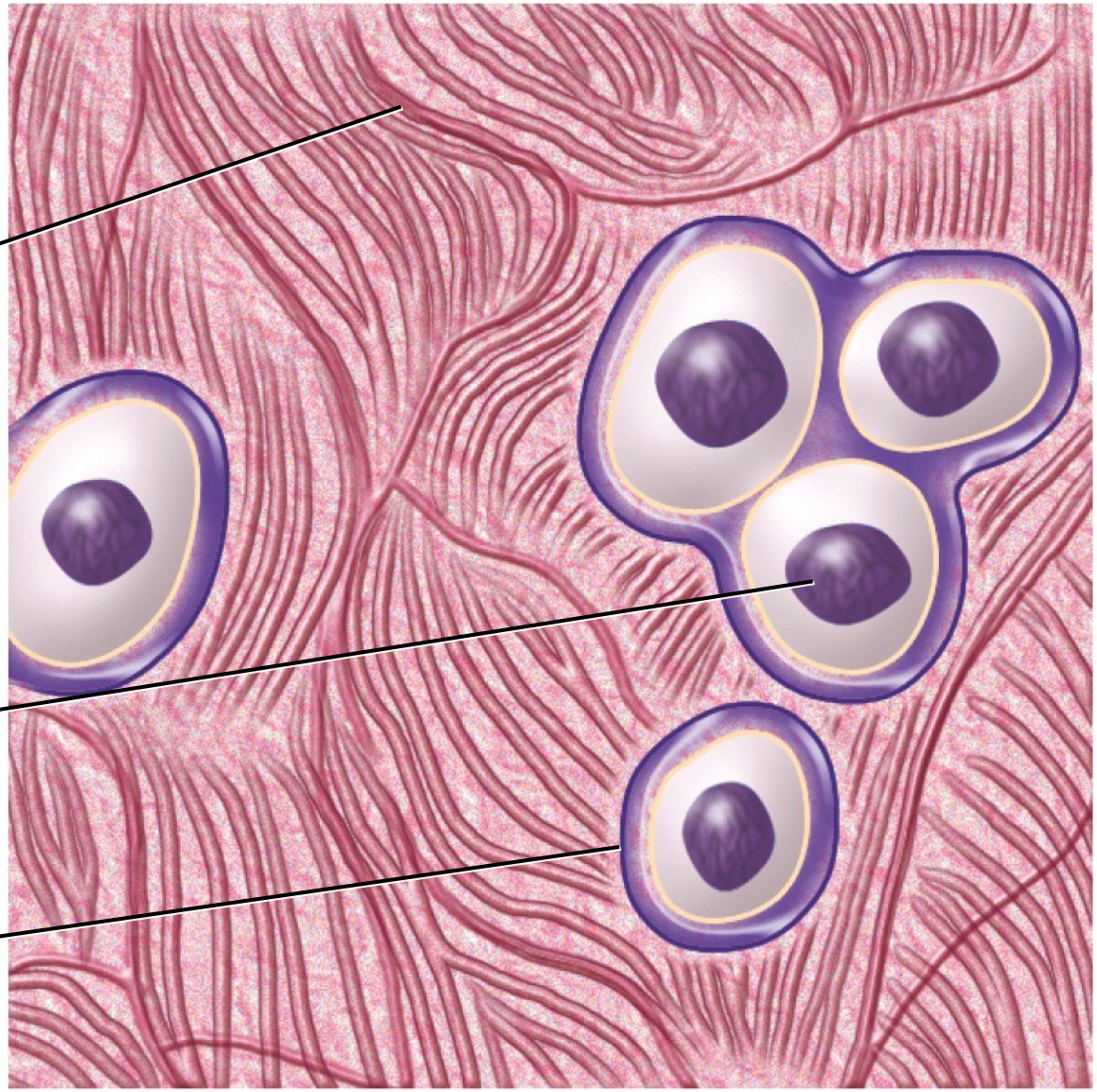

Fibrocartilage

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Elastic Cartilage

TABLE 3.6

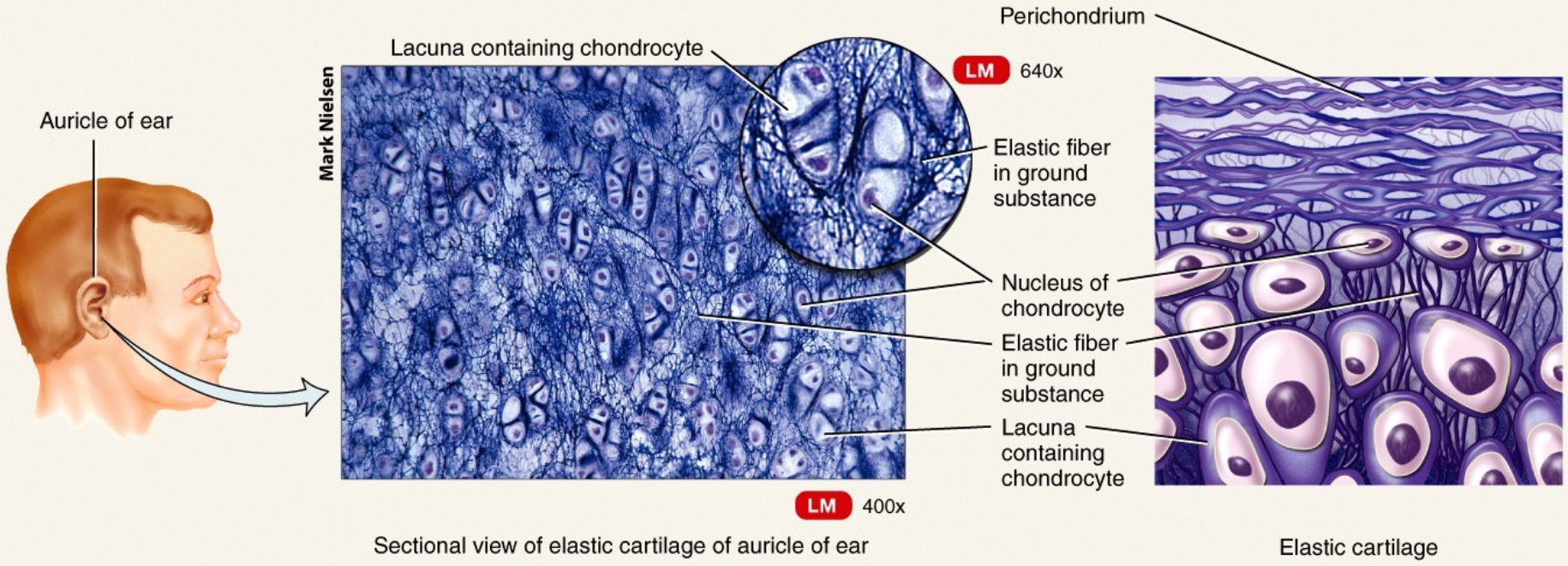
Mature Connective Tissue: Cartilage

C. ELASTIC CARTILAGE

Description: Consists of chondrocytes located in a threadlike network of elastic fibers within the extracellular matrix. A perichondrium is present.

Location: Lid on top of larynx (epiglottis), part of external ear (auricle), and auditory (eustachian) tubes.

Function: Provides strength and elasticity and maintains shape of certain structures.



Sectional view of elastic cartilage of auricle of ear

Elastic cartilage

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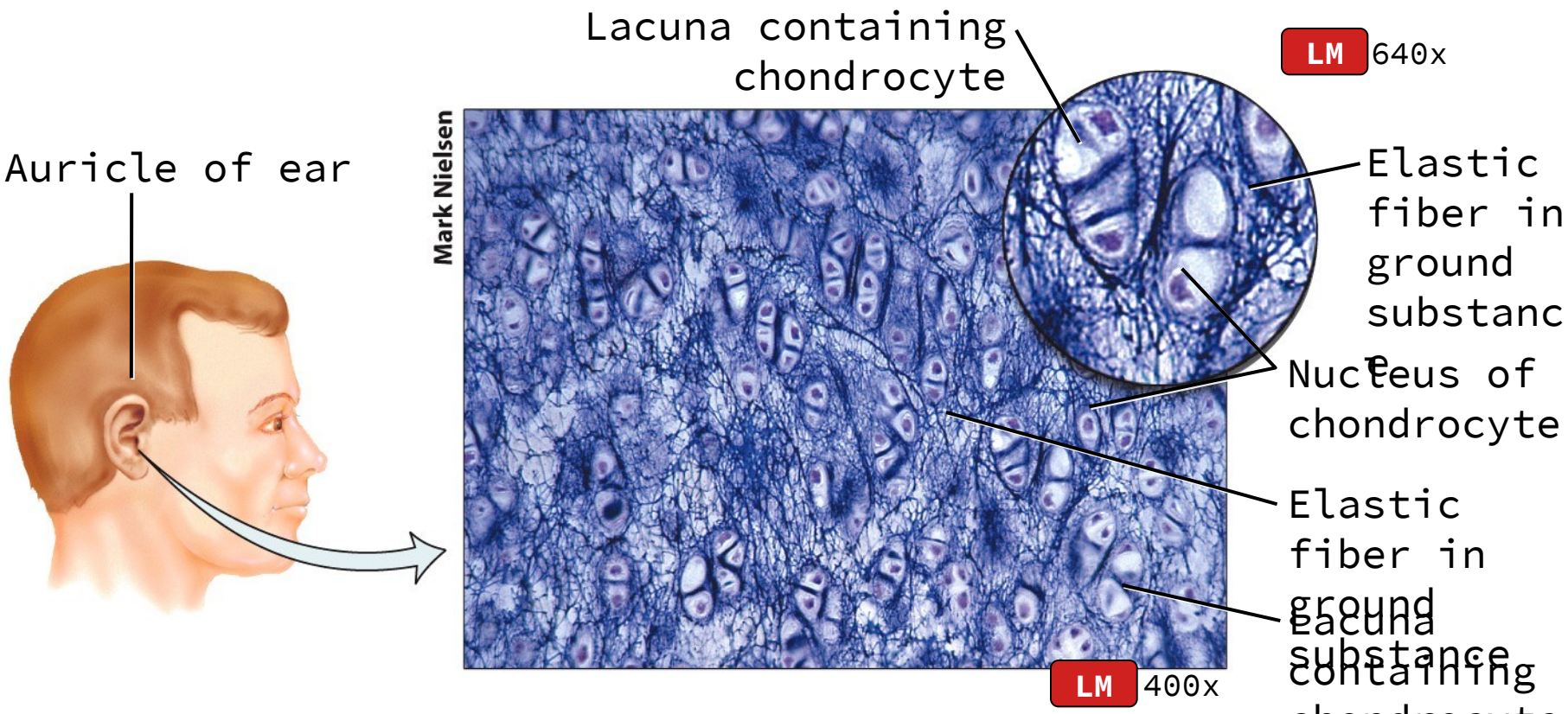

Sectional view of elastic cartilage of auricle of ear

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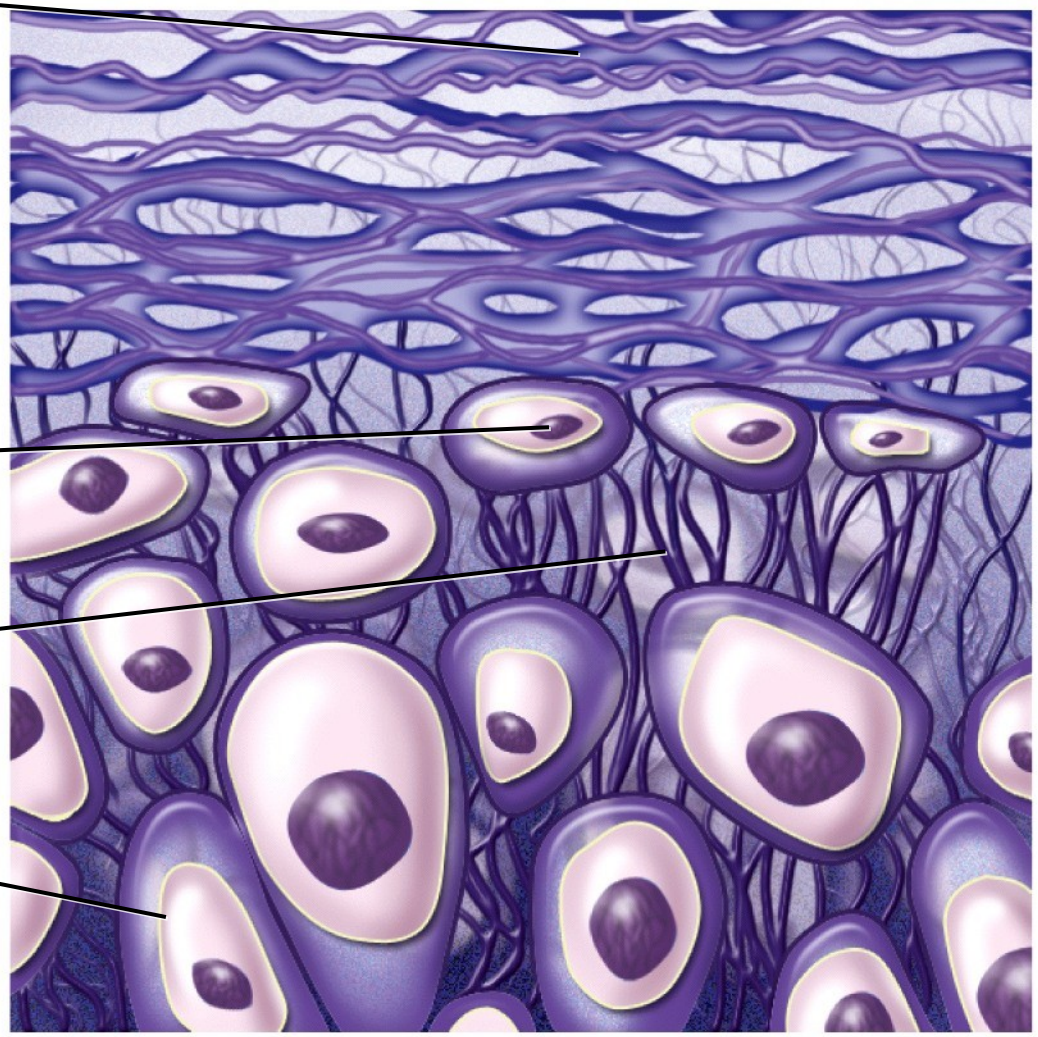

Elastic cartilage

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Clinical Connection

Tissue engineering

- combines synthetic material with cells
- has allowed scientists to grow new tissues in the laboratory to replace damaged tissues in the body
- some already developed or being developed:
  - skin and cartilage
  - bones, tendons, heart valves, bone marrow, and intestines

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Clinical Connection

Tissue engineers have already developed laboratory-grown versions of skin and cartilage using scaffolding beds of biodegradable synthetic materials or collagen as substrates that permit body cells to be cultured. As the cells divide and assemble, the scaffolding degrades; the new, permanent tissue is then implanted in the patient.

Other structures currently under development include bones, tendons, heart valves, bone marrow, and intestines. Work is also under way to develop insulin-producing cells for diabetics, dopamine-producing cells for Parkinson disease patients, and even entire livers and kidneys.

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Mature connective tissue

- Loose connective tissue
  - Areolar connective tissue
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- Dense connective tissue
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- Cartilage
  - Hyaline cartilage
  - Fibrocartilage
  - Elastic cartilage
- Bone tissue
- Liquid connective tissue
  - Blood tissue
  - Lymph

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Bone Tissue

TABLE 3.7

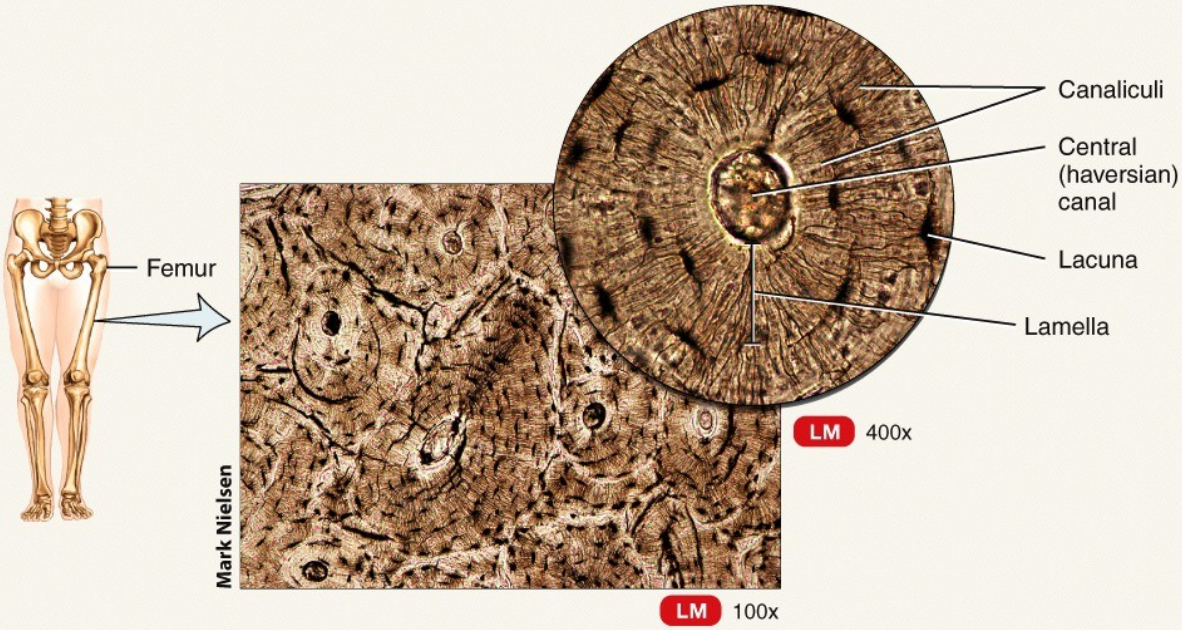
Mature Connective Tissue: Bone Tissue

COMPACT BONE

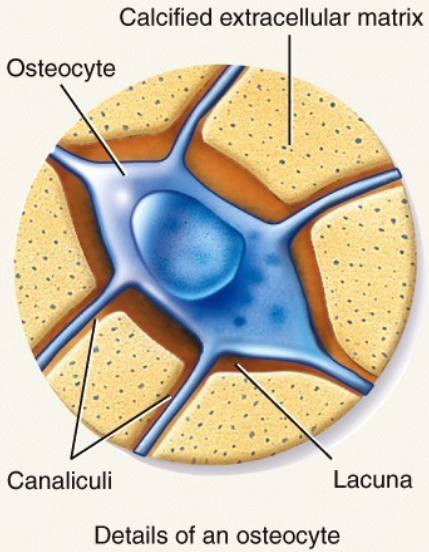
Description: The basic unit of compact bone tissue is an osteon (haversian system) that contains lamellae, lacunae, osteocytes, canaliculi, and central (haversian) canals (see below). By contrast, spongy bone tissue (see Figure 6.4a, b) consists of thin columns called trabeculae; spaces between trabeculae are filled with red bone marrow.

Location: Both compact and spongy bone tissue make up the various parts of bones of the body.

Function: Support, protection, storage; houses blood-forming tissue; serves as levers that act with muscle tissue to enable movement.



Sectional view of several osteons (haversian systems) of femur (thigh bone)



Details of an osteocyte

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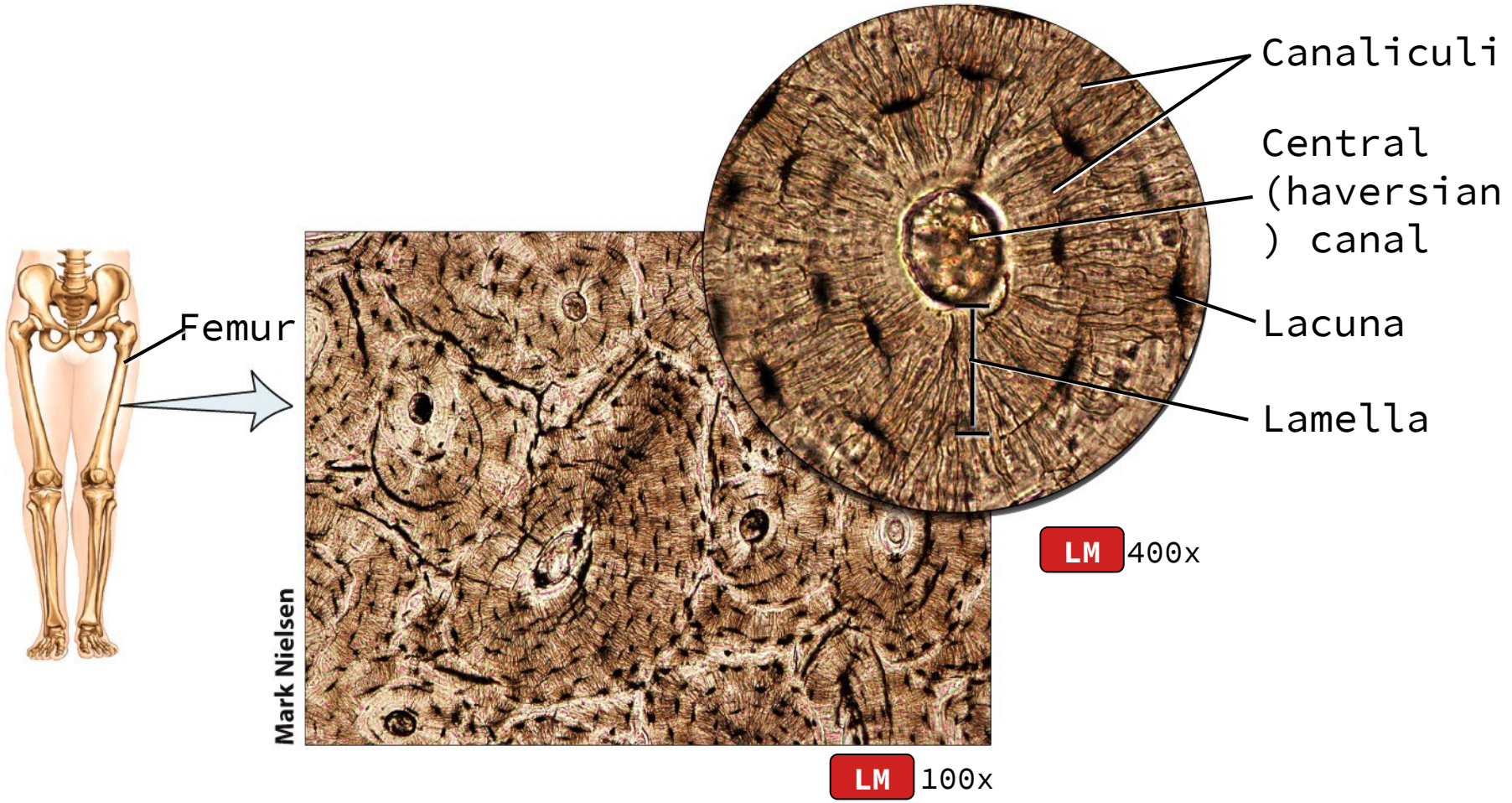

Sectional view of several osteons (haversian systems) of bone)

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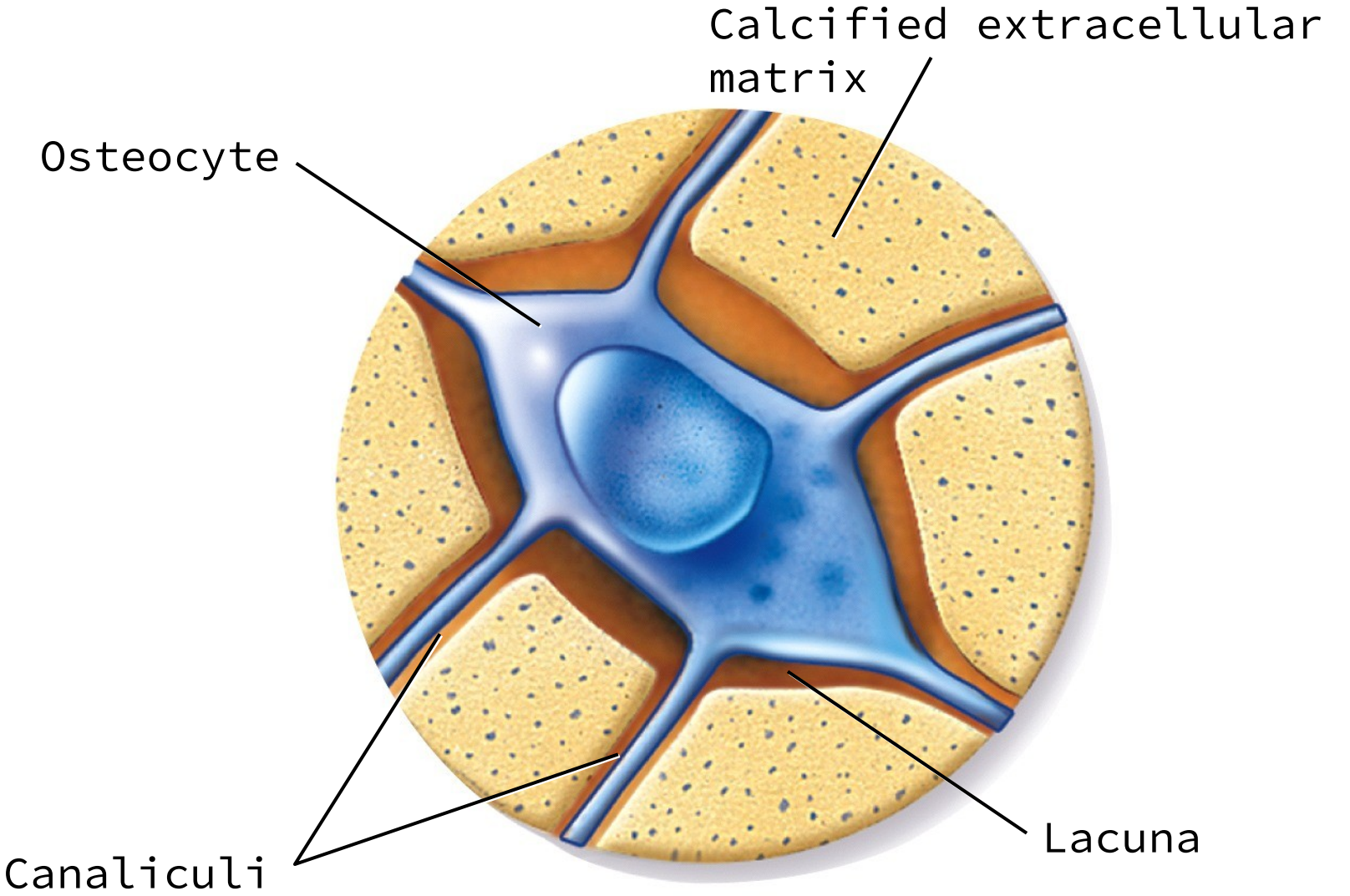

Details of an osteocyte

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Bone Tissue

contains **osteocytes** embedded in **lacunae** (with **canaliculi**) of a rigid, calcified matrix that includes collagen fibers; it is classified as:

- **Compact bone** composed of **osteons (haversian systems)** in which there are concentric rings of matrix called **lamellae;** each osteon contains a **central (haversian) canal**

- **Spongy bone** consisting of **trabeculae**; spaces between the trabeculae contain red bone marrow

Bone supports, protects, helps generate movement, stores minerals, and houses red marrow and yellow marrow.

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Mature connective tissue

- Loose connective tissue
  - Areolar connective tissue
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  - Dense irregular connective tissue
  - Elastic connective tissue
- Cartilage
  - Hyaline cartilage
  - Fibrocartilage
  - Elastic cartilage
- Bone tissue
- Liquid connective tissue
  - Blood tissue
  - Lymph

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Blood – Liquid Connective Tissue

TABLE 3.8

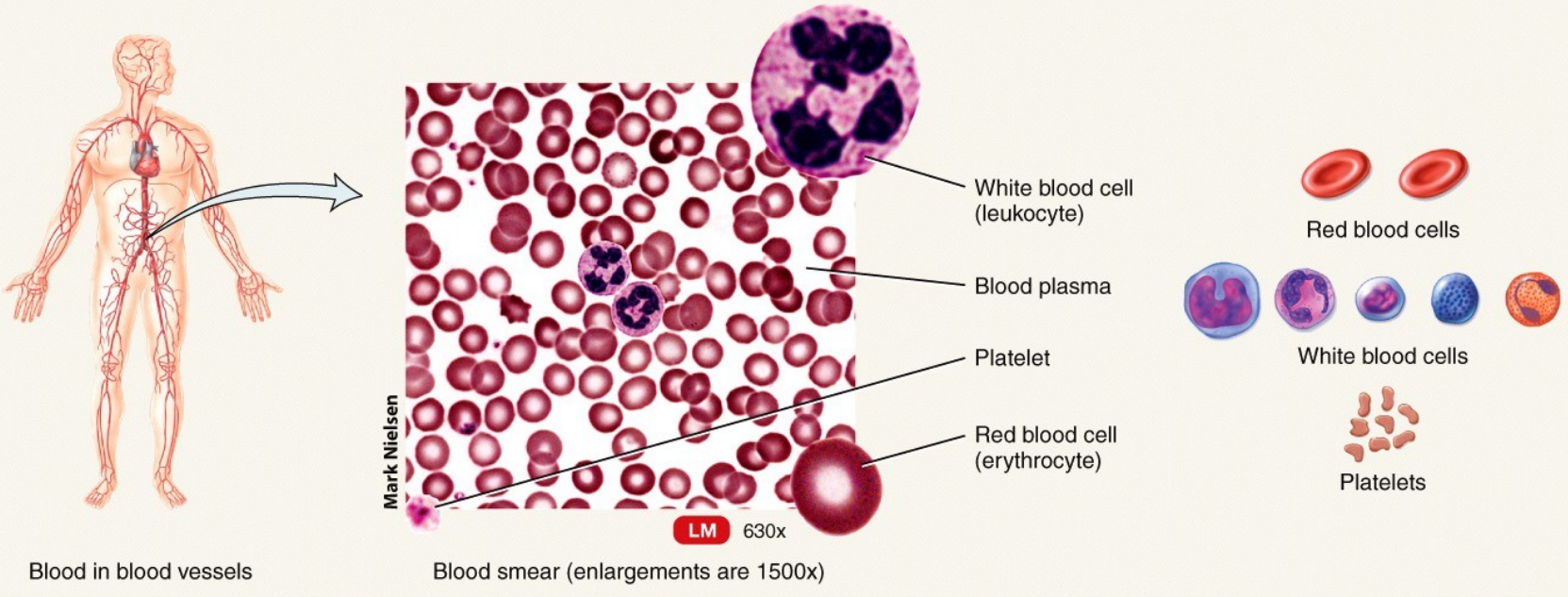
Mature Connective Tissue: Liquid Connective Tissue

BLOOD

Description: Consists of blood plasma and formed elements: red blood cells (erythrocytes), white blood cells (leukocytes), and platelets (thrombocytes).

Location: Within blood vessels (arteries, arterioles, capillaries, venules, and veins) and within the chambers of the heart.

Function: Red blood cells transport oxygen and some carbon dioxide; white blood cells carry on phagocytosis and are involved in allergic reactions and immune system responses; platelets are essential for the clotting of blood.



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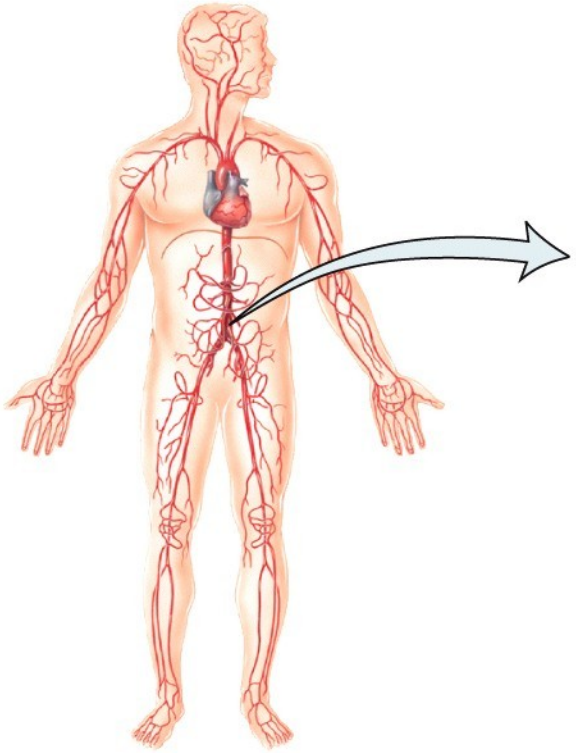
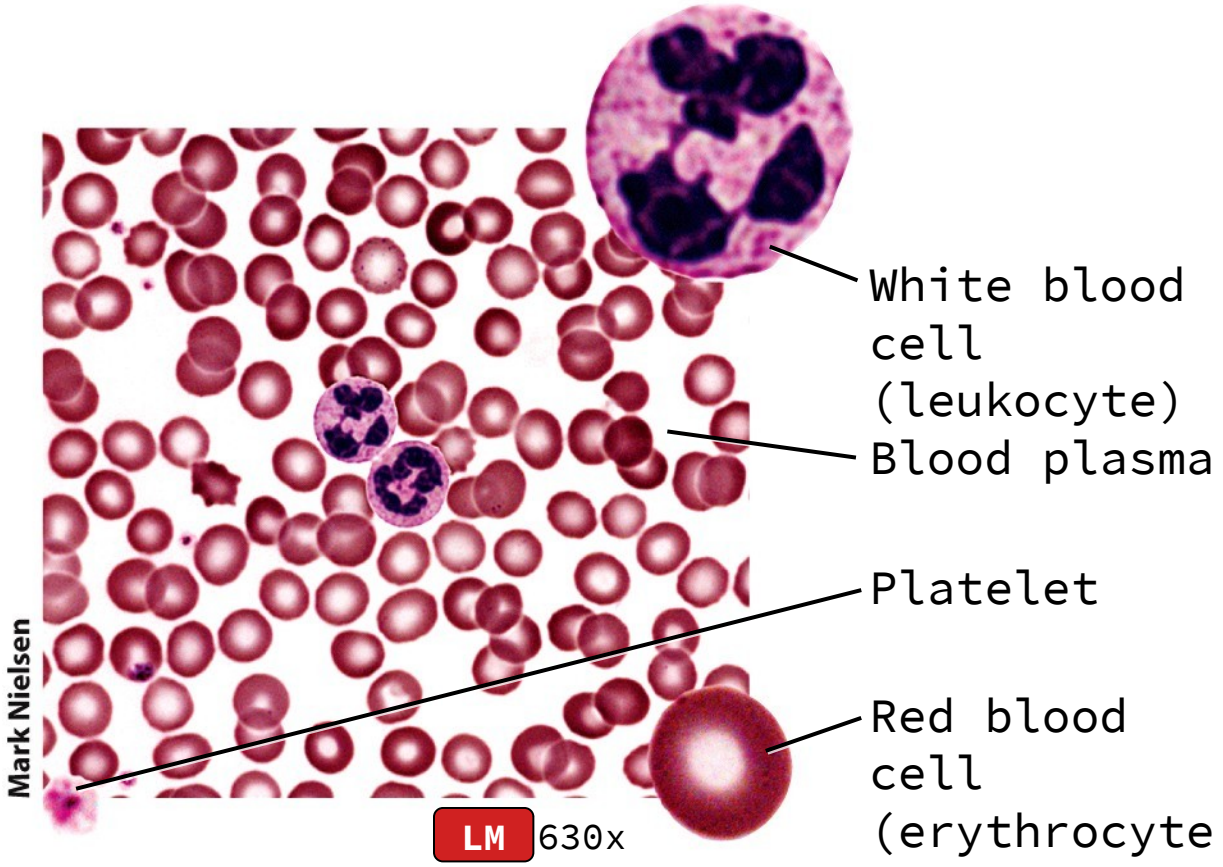


Blood in blood vessels



Blood smear (all enlargements are 1500x)

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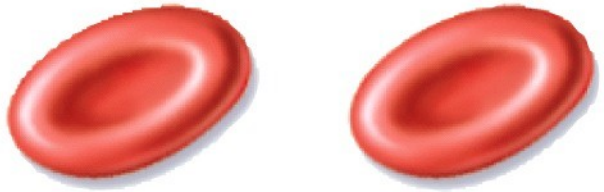
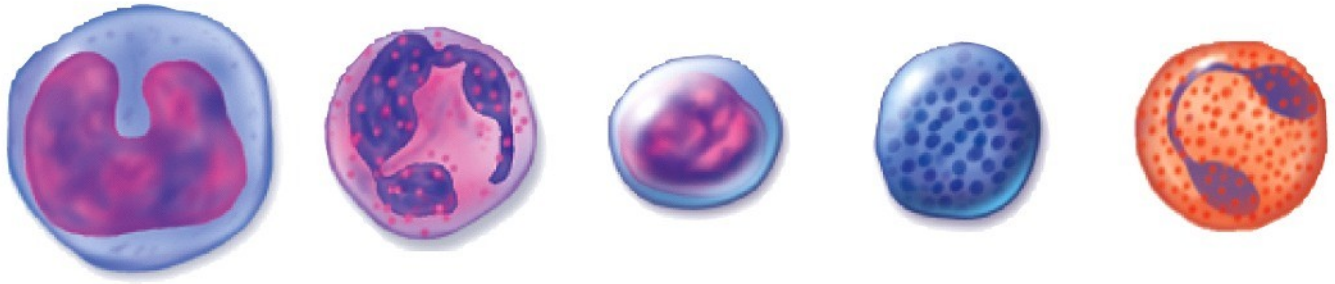


Red blood cells



White blood cells

Platelets

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Blood – Liquid Connective Tissue

Blood tissue consists of a liquid matrix called **plasma** in which the following **formed elements** are suspended:

- **Erythrocytes** (red blood cells) transport the gases oxygen and carbon dioxide
- **Leukocytes** (white blood cells) are involved in phagocytosis, immunity, and allergic reactions
- **Thrombocytes (**platelets) play a role in blood clotting

Lymph is interstitial fluid that flows in lymphatic vessels.

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Membranes

- Epithelial membranes
  - Mucous membranes (mucosa)
  - Serous membranes (serosa)
  - Cutaneous membrane (skin)
- Synovial membranes

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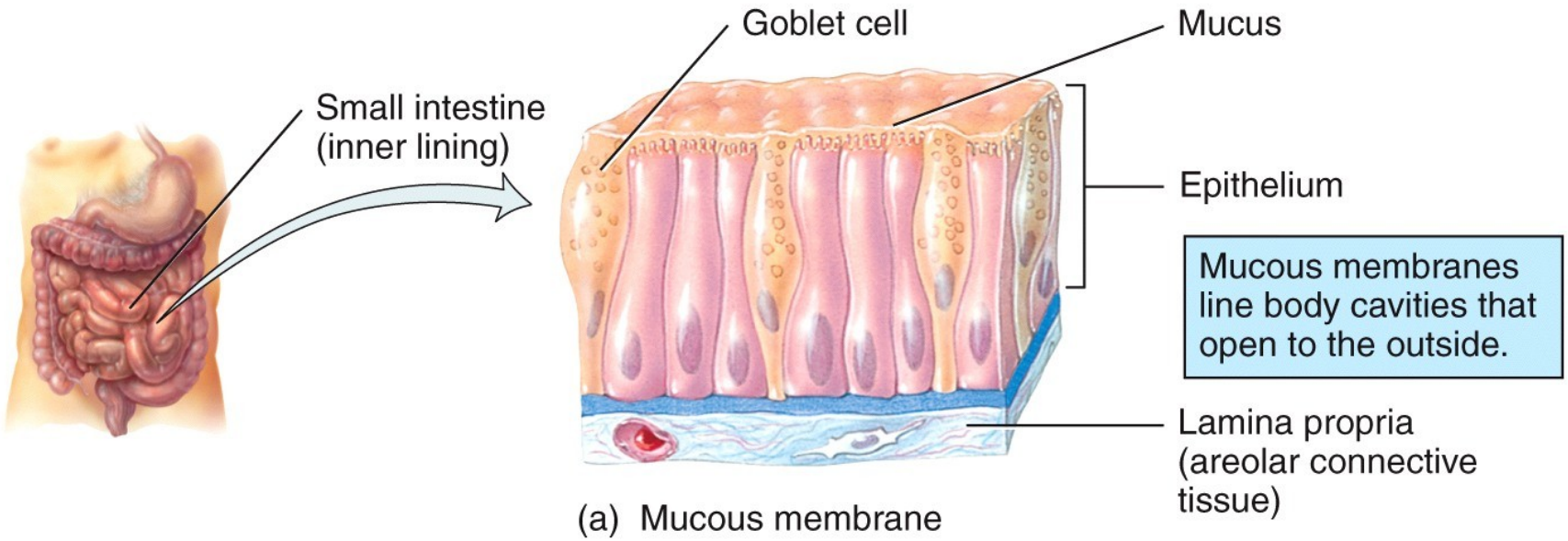
Membranes



Mucous membrane (mucosa) lines a cavity that opens to the exterior (e.g., gastrointestinal tract, respiratory tract, etc.); it forms a barrier against entry of microbes, secretes mucus to prevent dehydration and trap pathogens, etc.; the connective tissue layer is called lamina propria

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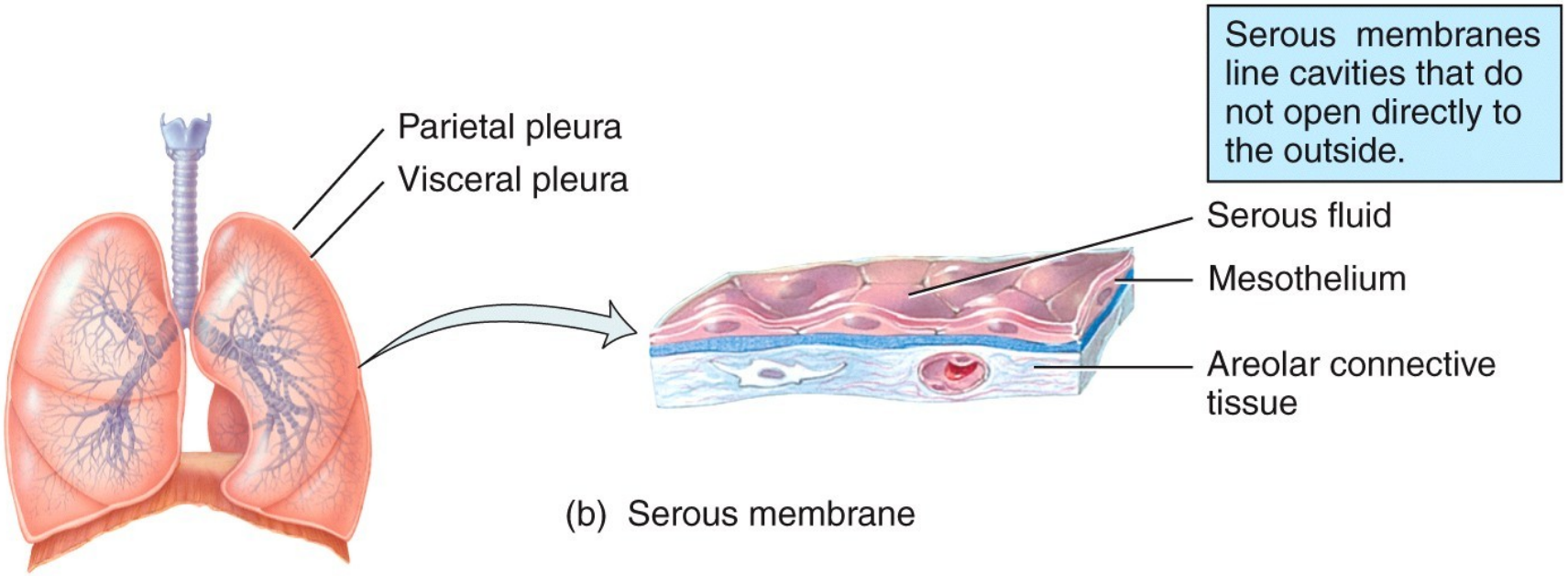
Membranes



Serous membrane (serosa) lines (parietal layer) a body cavity that does not open to the exterior (e.g., thoracic cavity, abdominal cavity), and it covers (visceral layer) organs inside these cavities (e.g., lungs, stomach); the epithelial layer secretes a lubricating serous fluid that reduces friction between the organs and the walls of the cavities; examples include the pericardium, pleura and peritoneum

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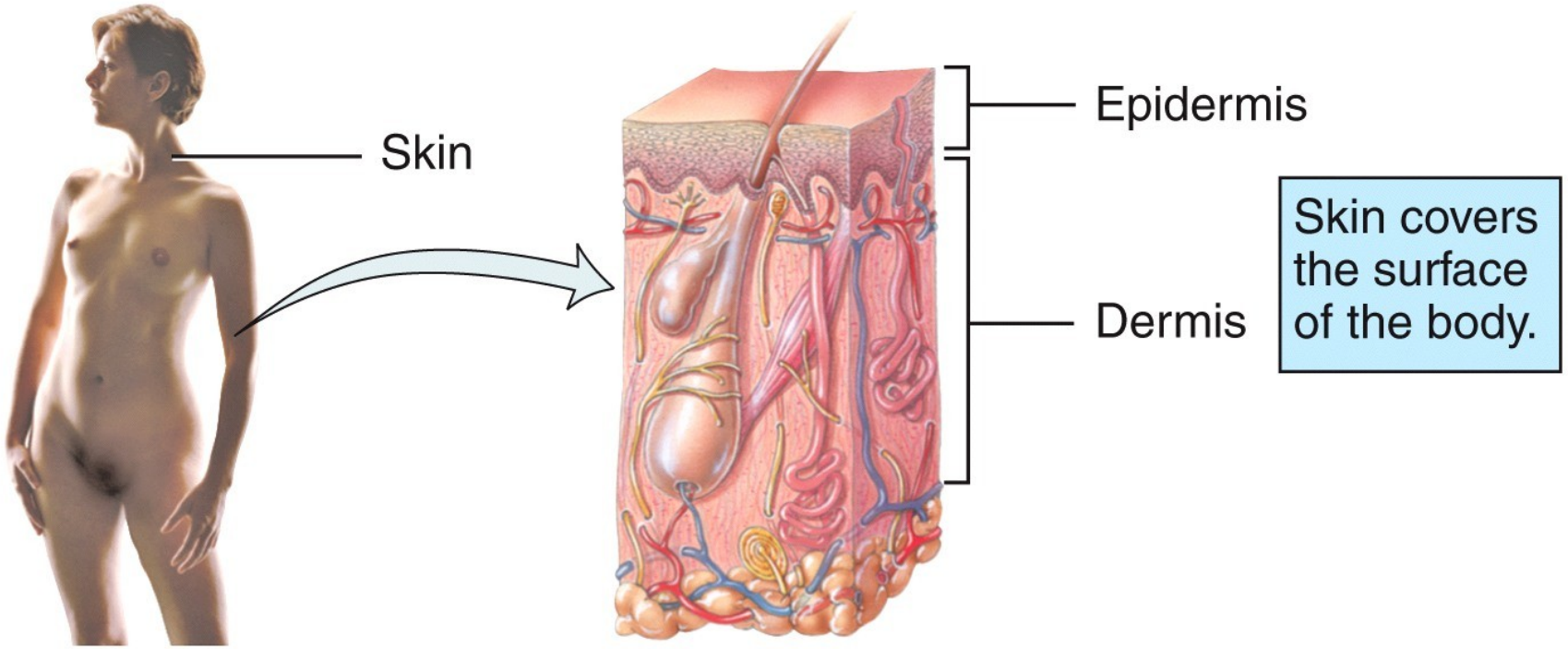
Membranes



(c) Skin (cutaneous membrane)

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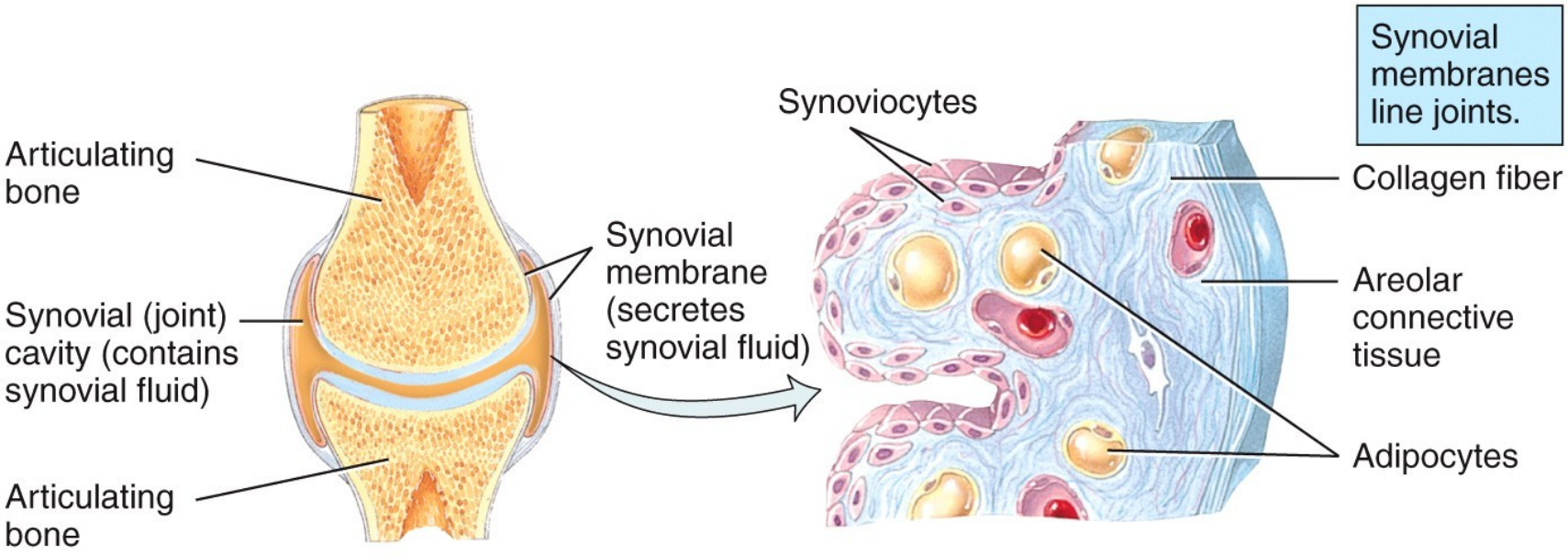
Membranes



(d) Synovial membrane

Synovial membranes (which lack an epithelial layer) line joint cavities, bursae, and tendon sheaths; synoviocytes secrete components of a lubricating synovial fluid that reduces friction during movements.

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Muscular Tissue

- Muscular tissue consists of cells, usually called muscle fibers
- There are three major types
  - Skeletal
  - Cardiac
  - Smooth

Muscular tissue consists of cells, usually called muscle fibers (myocytes), that are specialized to contract and therefore provide motion, maintain posture, generate heat and provide protection.

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Muscular Tissue

TABLE 3.9

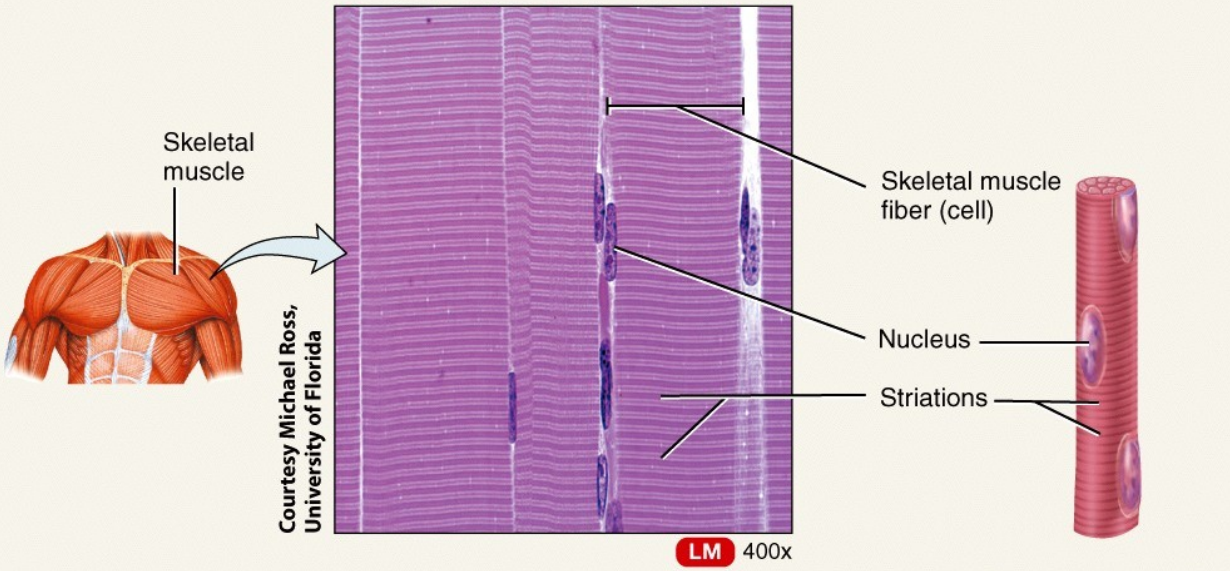
Muscular Tissue

A. SKELETAL MUSCLE TISSUE

Description: Consists of long, cylindrical, striated fibers (alternating light and dark bands within the fibers called *striations* that are visible under a light microscope). Skeletal muscle fibers can vary greatly in length, ranging from a few centimeters in short muscles to up to 30–40 cm (about 12–16 in.) in your longest muscles. Roughly cylindrical in shape, a muscle fiber is a multinucleated cell with the nuclei located at the cell's periphery. Skeletal muscle is considered *voluntary* because it can be made to contract or relax by conscious control.

Location: Usually attached to bones by tendons.

Function: Motion, posture, heat production, and protection.



Longitudinal section of skeletal muscle tissue

Skeletal muscle fiber

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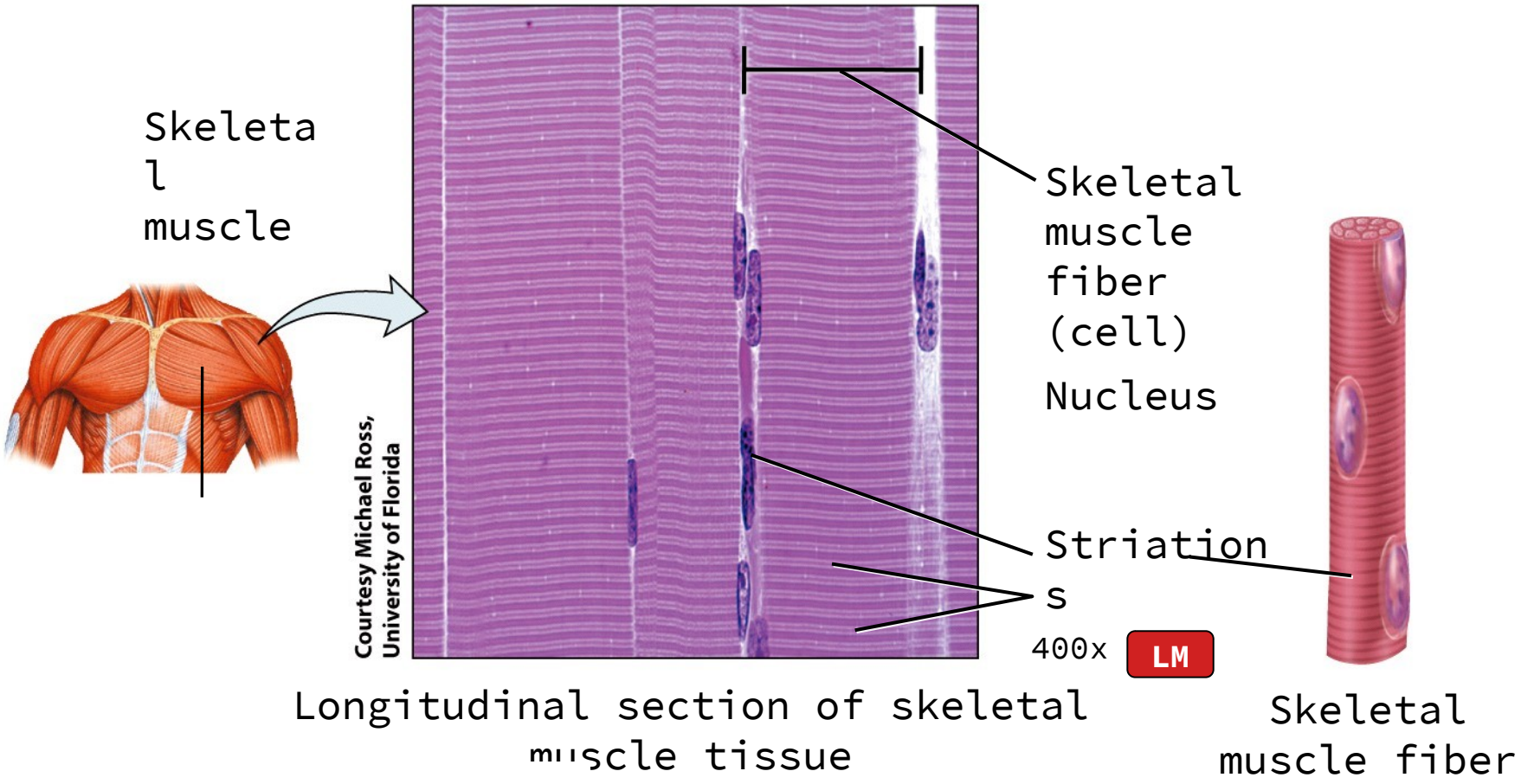

Skeletal muscle tissue is attached to bones and consists of long, cylindrical cells that are striated and multinucleate; it is under voluntary control

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Cardiac Tissue

TABLE 3.9

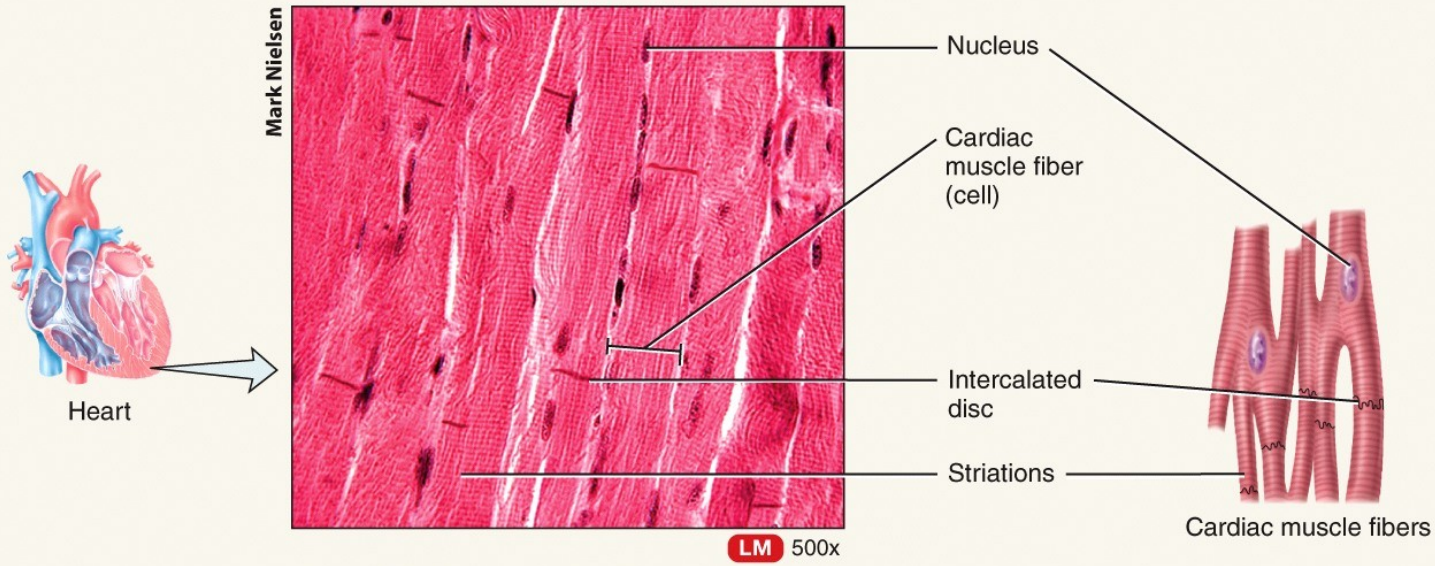
Muscular Tissue

B. CARDIAC MUSCLE TISSUE

Description: Cardiac muscle fibers are branched and usually have only one centrally located nucleus; an occasional cell has two nuclei. They attach end to end by transverse thickenings of the plasma membrane called *intercalated discs* (in-TER-ka-lāt-ed; *intercalate*=to insert between), which contain both desmosomes and gap junctions. Intercalated discs are unique to cardiac muscle tissue. The desmosomes strengthen the tissue and hold the fibers together during their vigorous contractions. The gap junctions provide a route for quick conduction of electrical signals called muscle action potentials throughout the heart. *Involuntary* control, meaning it is not consciously controlled.

Location: Heart wall.

Function: Pumps blood to all parts of the body.



Longitudinal section of cardiac muscle tissue

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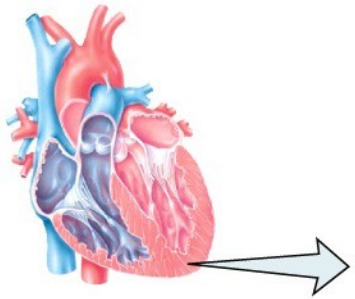
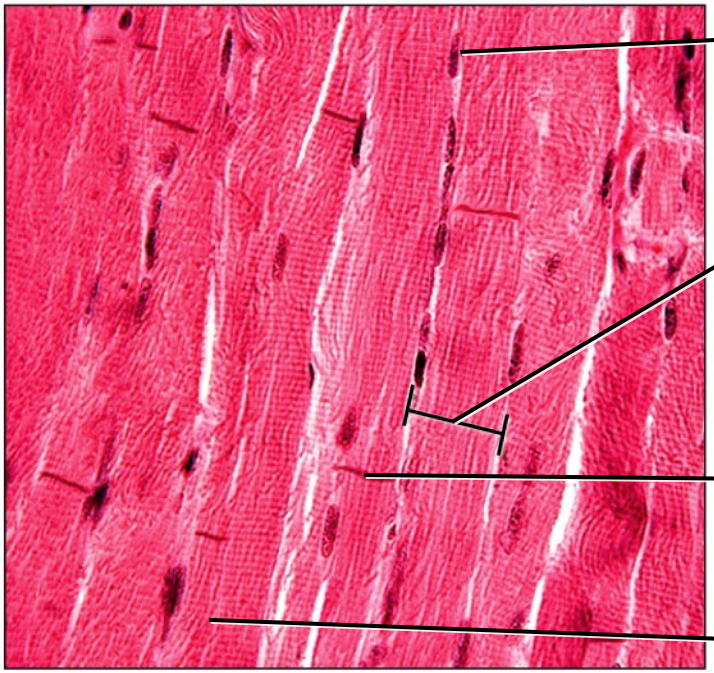
Cardiac Tissue



Heart



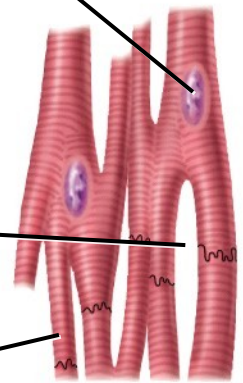
Longitudinal section of cardiac
le tissue

Nucleus

Cardiac muscle fiber (cell)

Intercalated disc

Striations



Cardiac muscle fibers

Cardiac muscle tissue forms most of the wall of the heart and consists of striated, branching cells connected by intercalated discs; it is under involuntary control

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Smooth Muscle Tissue

TABLE 3.9

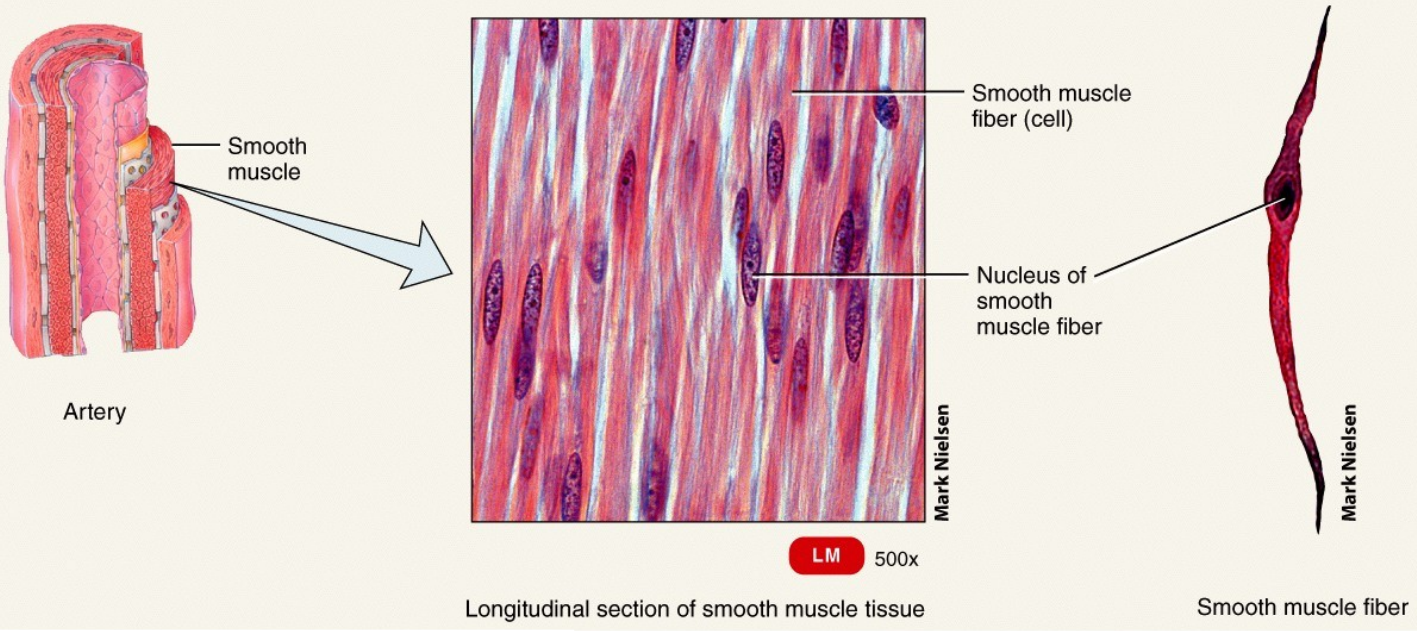
Muscular Tissue

C. SMOOTH MUSCLE TISSUE

Description: Smooth muscle fibers are usually *involuntary*, and they are nonstriated (lack striations), hence the term *smooth*. A smooth muscle fiber is a small spindle-shaped cell that is thickest in the middle and tapers at each end. It contains a single, centrally located nucleus. Gap junctions connect many individual fibers in some smooth muscle tissues, for example, in the wall of the intestines. Such muscle tissues can produce powerful contractions as many muscle fibers contract in unison. In other locations, such as the iris of the eye, smooth muscle fibers contract individually, like skeletal muscle fibers, because gap junctions are absent.

Location: Iris of the eyes, walls of hollow internal structures such as blood vessels, airways to the lungs, stomach, intestines, gallbladder, urinary bladder, and uterus.

Function: Motion (constriction of blood vessels and airways, propulsion of foods through gastrointestinal tract, contraction of urinary bladder and gallbladder).



Longitudinal section of smooth muscle tissue

Smooth muscle fiber

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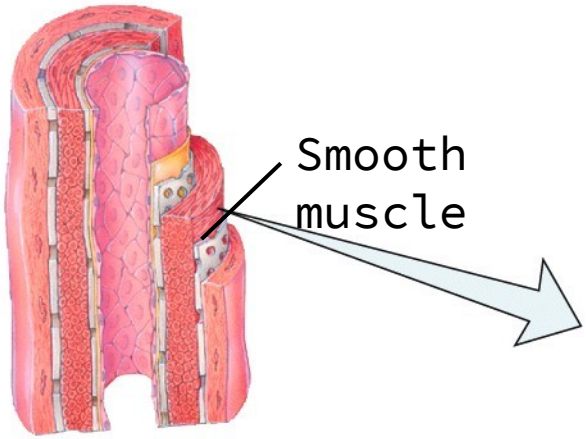
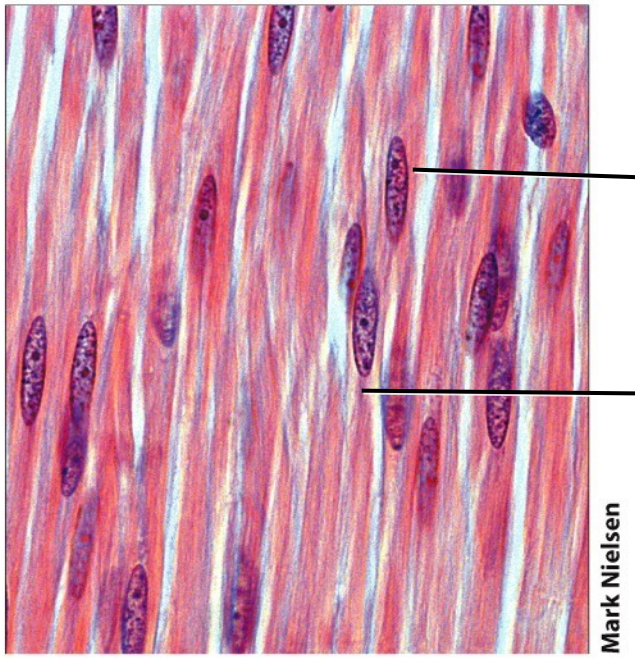
Smooth Muscle Tissue



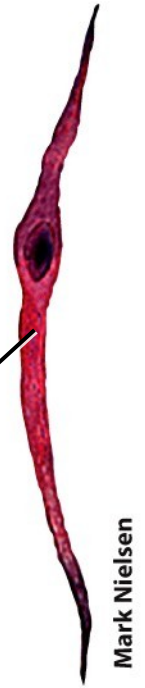
Smooth muscle

Artery



Smooth muscle fiber (cell)

Nucleus of smooth muscle fiber



LM 500x

Longitudinal section of smooth muscle tissue

Smooth muscle fiber

Smooth muscle tissue is located primarily in the walls of hollow internal organs (e.g., stomach, blood vessels, etc.) and consists of non-striated spindle-shaped cells; it is usually under involuntary control.

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Anatomy Overview:

- Muscle Tissue

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Nervous Tissue

Nervous tissue consists of *two major kinds of cells*

- **Neurons** detect stimuli, convert stimuli into **nerve action potentials** (nerve impulses), and conduct these messages to other neurons, muscle fibers or glands; neurons consist of:
  - **cell body** which contains the nucleus and most other organelles
  - branched processes called **dendrites**
  - process called **axon** which conducts nerve impulses away from the cell body
- **Neuroglia** provide protection and support to the neurons.

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Anatomy Overview:

- Nervous Tissue

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Nervous Tissue

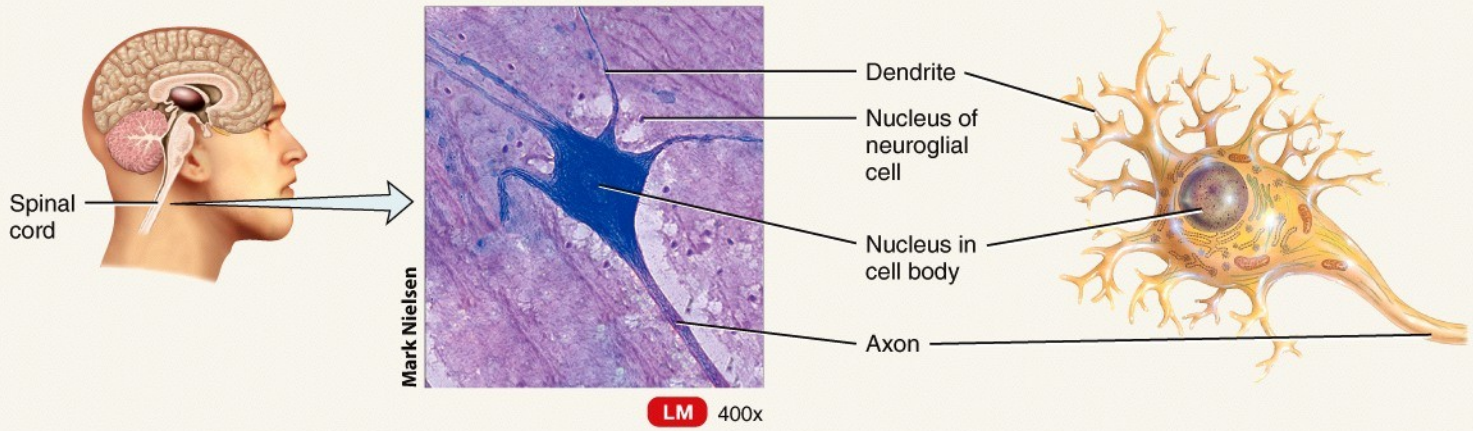
TABLE 3.10

Nervous Tissue

Description: Consists of neurons (nerve cells) and neuroglia. Neurons consist of a cell body and processes extending from the cell body (one to multiple dendrites and a single axon). Neuroglia do not generate or conduct nerve impulses but have other important supporting functions.

Location: Nervous system.

Function: Exhibits sensitivity to various types of stimuli, converts stimuli into nerve impulses (action potentials), and conducts nerve impulses to other neurons, muscle fibers, or glands.



Neuron of spinal cord

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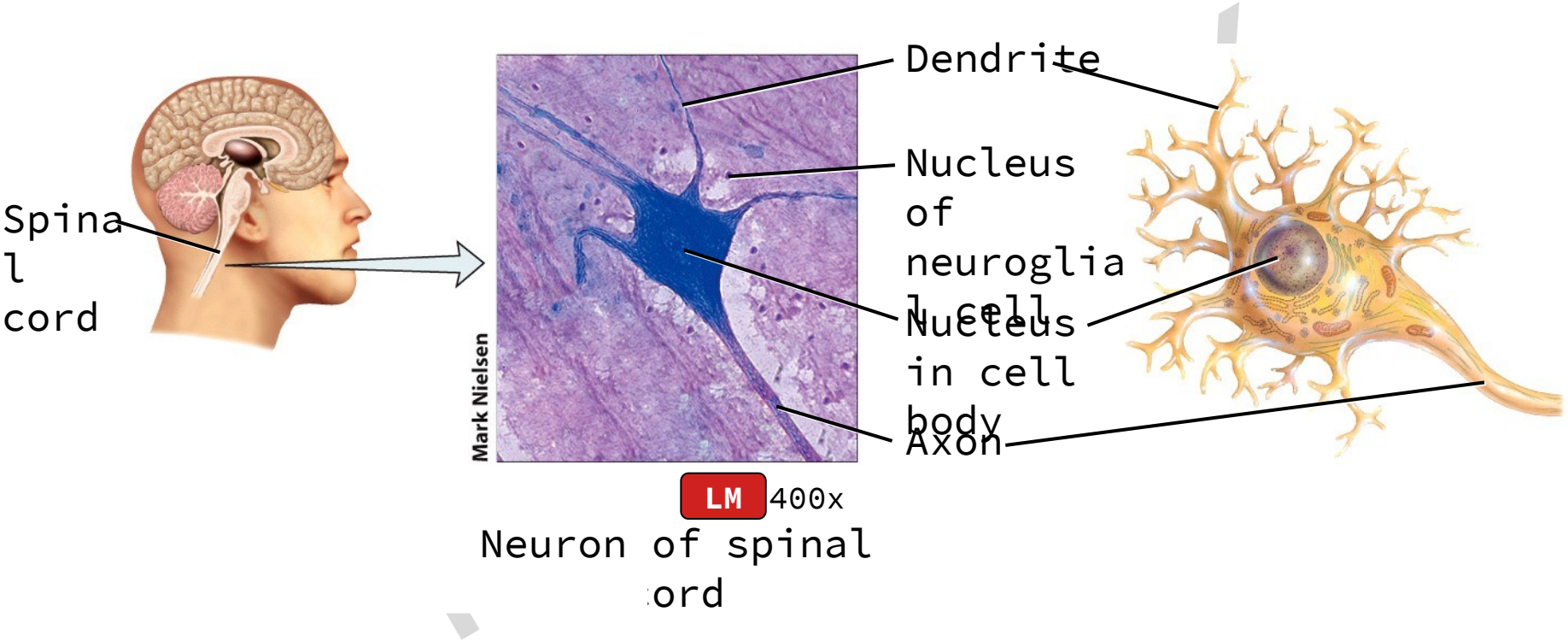

Neuron of spinal cord

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Aging and Tissues

- Tissues heal faster and leave less obvious scars in the young than in the aged
- The extracellular components of tissues, such as collagen and elastic fibers, change with age

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